Interactions among Biodiversity and Socioeconomics in the Greater Yellowstone Ecosystem

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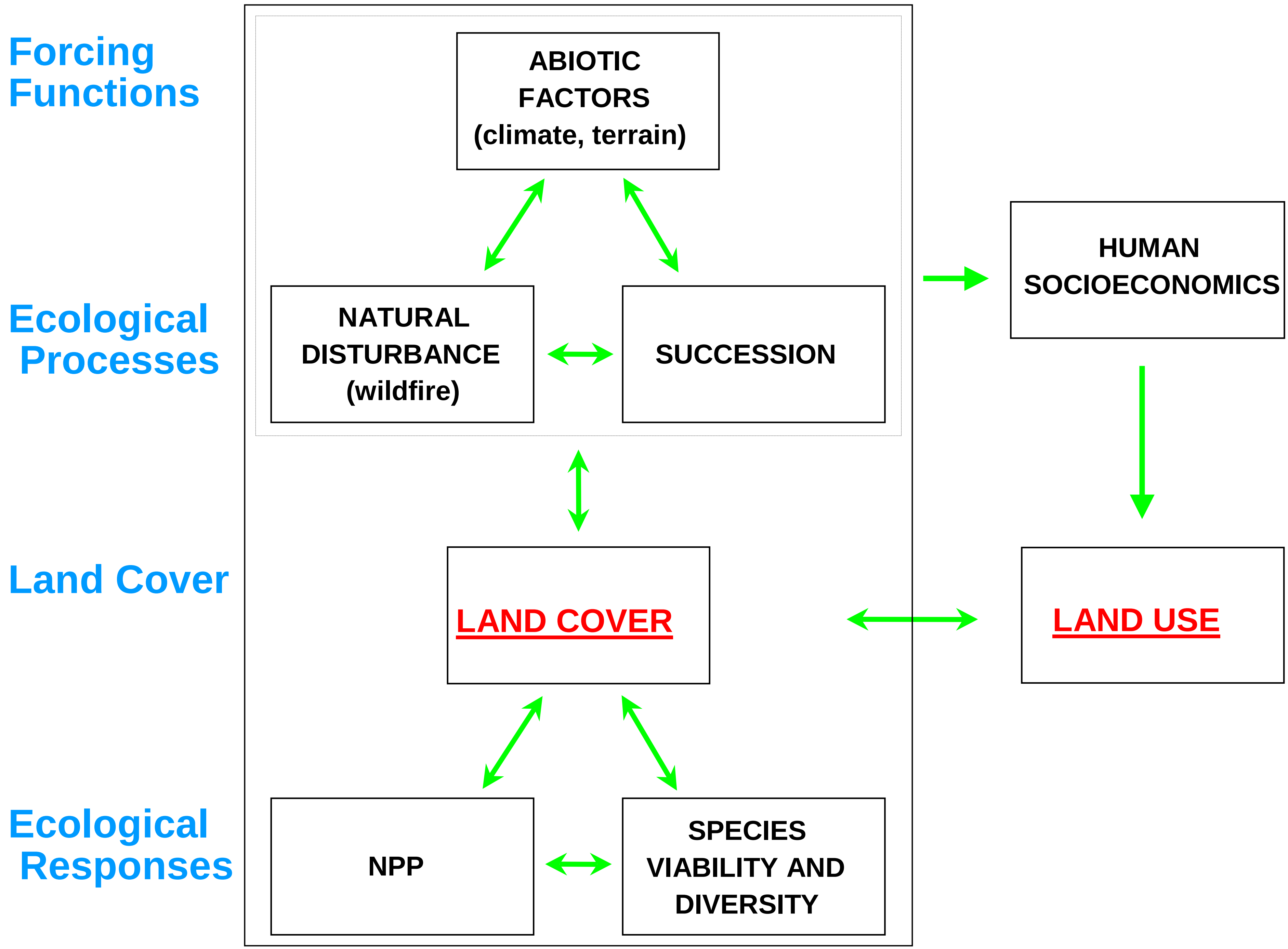
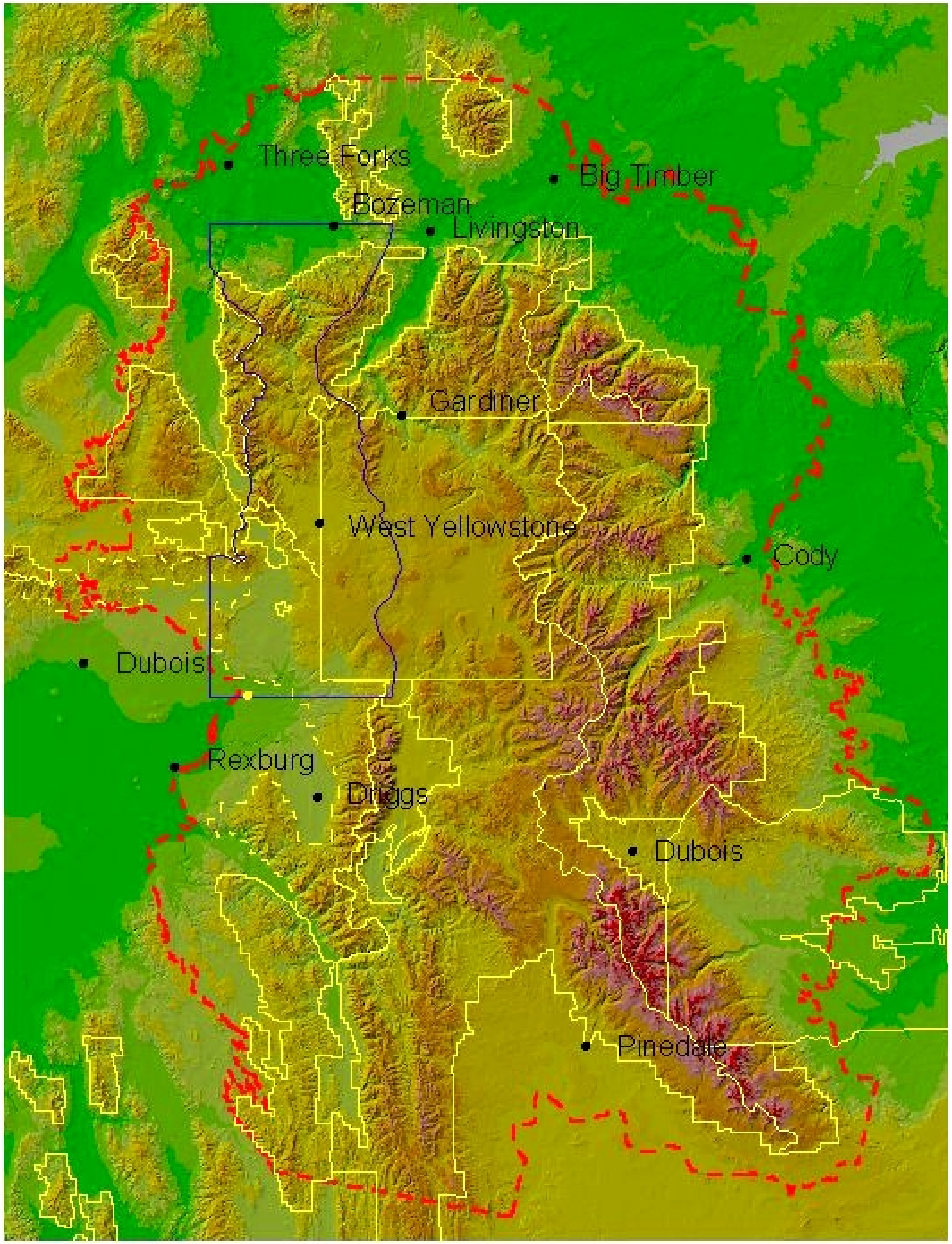
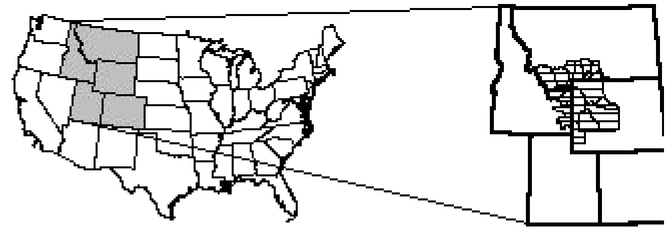
Funded by: NASA, USDA-NRI, USFS, MFWP, USFWS


Forcing Functions
Ecological Processes
Land Cover
Ecological Responses
ABIOTIC FACTORS (climate, terrain)
NATURAL DISTURBANCE (wildfire)
SUCCESSION
HUMAN SOCIOECONOMICS
LAND COVER
LAND USE
NPP
SPECIES VIABILITY AND DIVERSITY

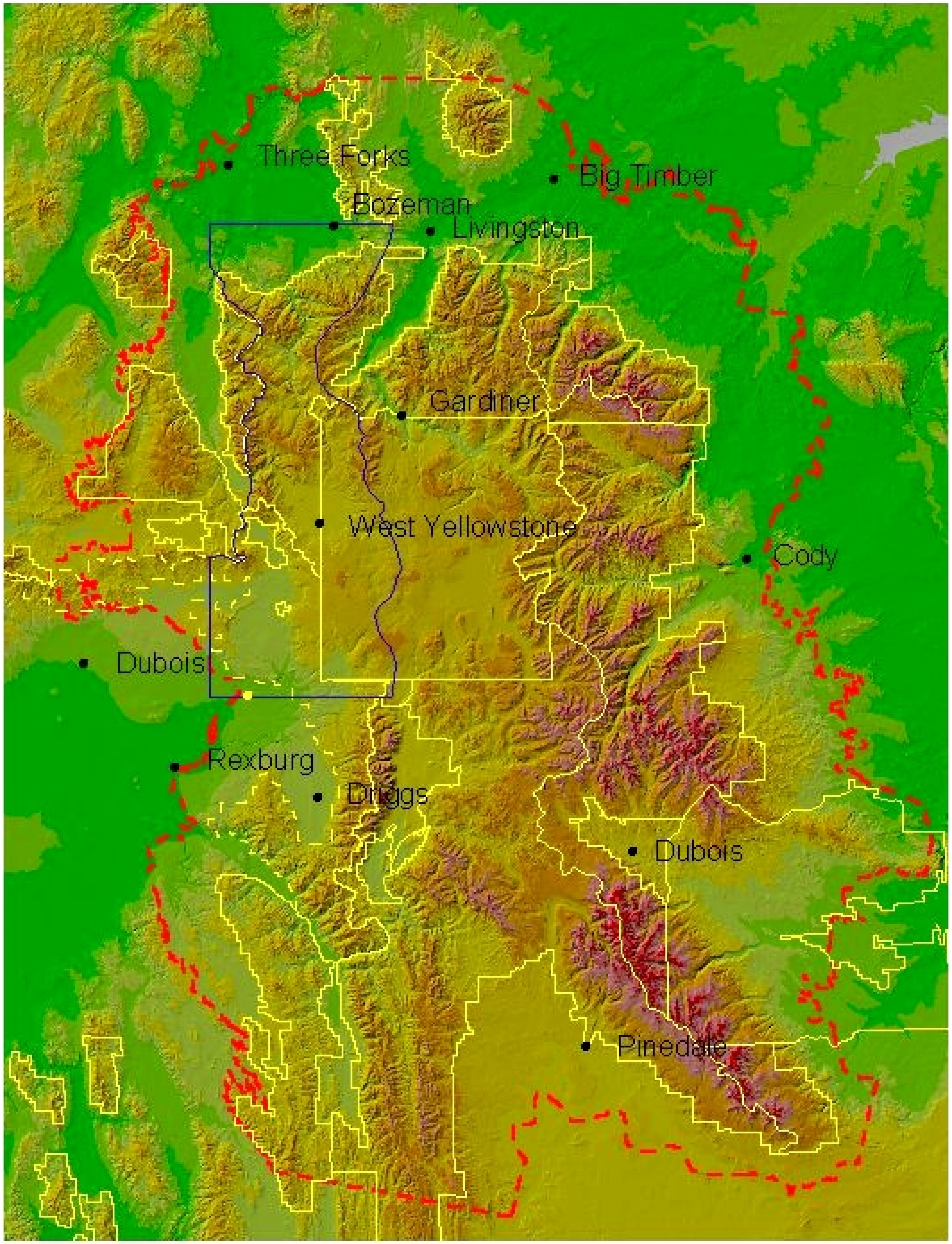
Objectives

- **1. 25-Year History of GYE:** **Quantify changes in biophysical gradients, biodiversity, and land use and socioeconomic factors across the GYE from 1972-1996.**
- **2. Causes and Consequences:** **Test hypotheses on interactions among biophysical gradients, biodiversity, and socioeconomic patterns.**
- **3. Risk: Assess current and future risk to ecological hot spots and potential for restoration.**
- **4. Pulse Taking: Develop and implement an approach to monitor ecological and human interactions.**
- **5. Policy: Communicate results to stakeholders.**





Study Area Boundaries



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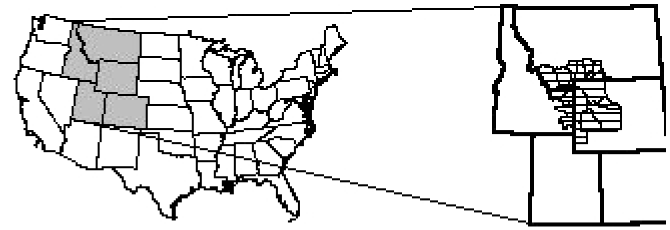


- 98,000-km^2
- 7 Landsat TM scenes
- 1500-3800 m elevatio
- 3 states
- 7 national forests
- 2 national parks
- 20 counties

Obj 1. 25-Year History of GYE

Variable	Source	Scale
Land cover/use	Landsat-TM, MSS	30-80 m
Biodiversity	Field/GIS	2 ha
Human Demographics	Census	County
Human Economics	Public records	100 m
Human Sociology	Bur. Econ. Ana.	County
Climate	PRISM	1 km

Land Cover Approach

Experimental Design

- **3 Pilot Areas**
- **3 Years of Imagery:** 1976, 1985, 1994
- **2 Dates per Year:** (June, August)

Each Pilot Area

- **Reference Data**: Collect calibration for each pilot area.
- **Classification Model:** Develop CART model.
- **Image Classification:** Apply CART model to image.
- **Change Detection:** Quantify change over time.

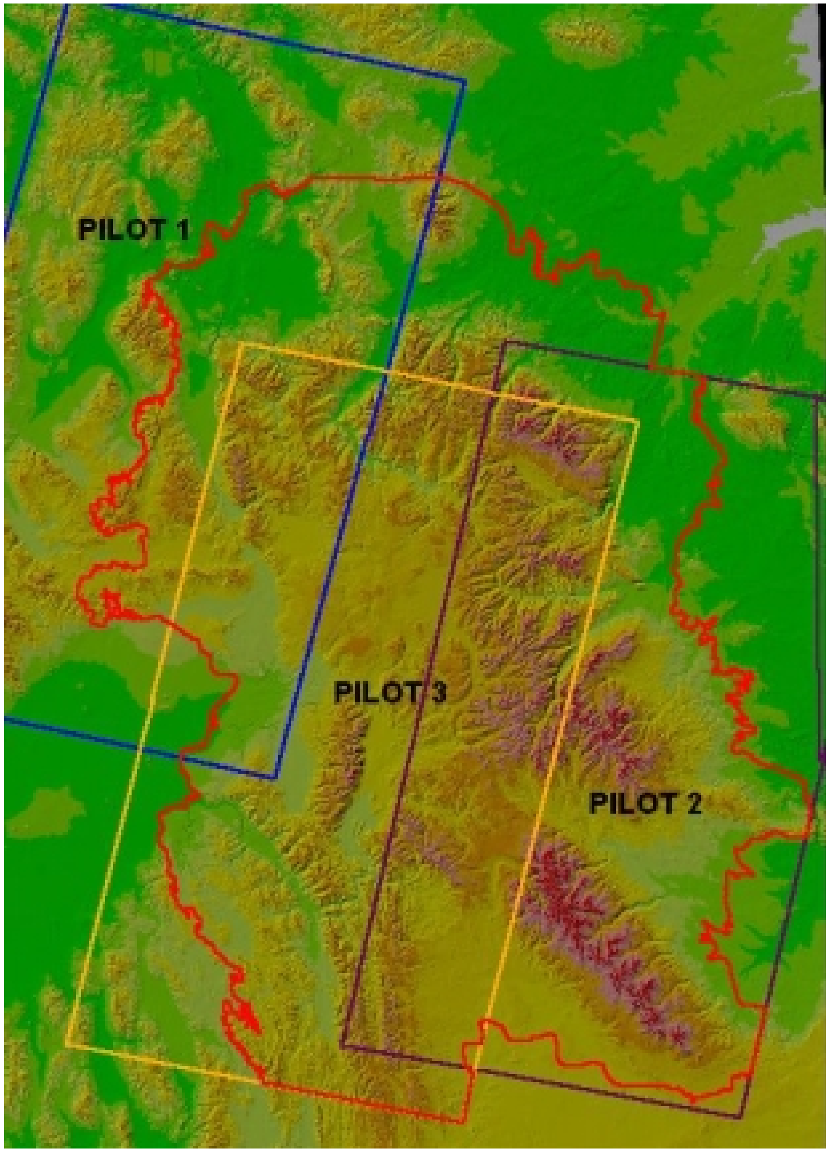
GYE-Wide

- **Image Classification:** Apply CART across GYE.

Land Cover Classes

LEVEL I	LEVEL II	LEVEL III
Non Veg	Snow/Ice/Cloud	
	Bareground/Rock	
	Water	
	Urban	
Agriculture	Agriculture	Perennial (Grazing/Pasture/CRP)
		Annual (Crop/Hay/Fallow)
Natural Vegetation	Conifer	- Conifer (mixed)
		- Douglas Fir
		- Clearcut
		- Burned
	Hardwood	- Aspen
		- Willow
		- Cottonwood
	Herbaceous	- Sage
		- Grassland

Pilot Areas

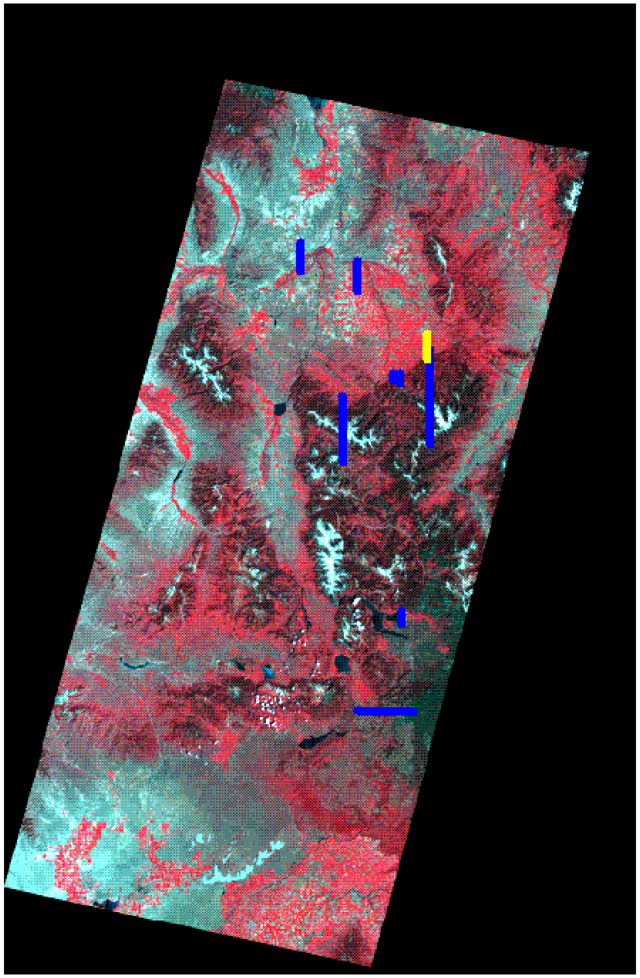


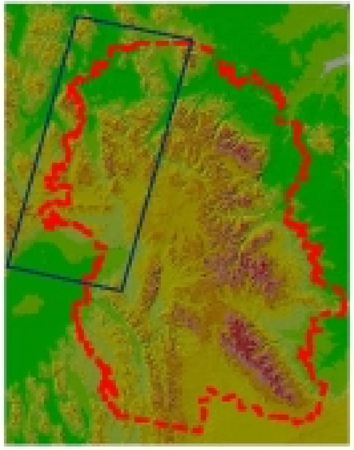
GYE Boundary
Pilot 1 Boundary
Pilot 2 Boundary
Pilot 3 Boundary

Reference Data Collection

- 1. Designate transects within pilot areas.
- 2. Identify random points along transects within cover type, elevation, aspect strata.
- 3. Sample 30-100 points per cover type distributed across elevation and aspect.

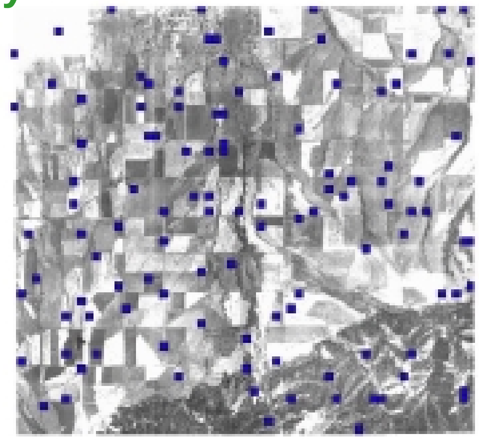
25-Year History - Land Cover





Transects for Reference Data: Pilot Area 1

25-Year History - Land Cover



Sample Points on Aerial Photos

Sample Points on Landsat Image

Land Cover Identification

Reference Data: Pilot Area 1

Number of Photo Interpreted Plots by Year and Land Cover				
Class		1976	1985	1994
LEVEL 1	Agriculture	198	181	194
	Non-Vegetation	383	372	340
	Natural Vegetation	25	21	18
	LEVEL 1 TOTALS	542	574	646
LEVEL 2	Conifer	148	160	171
	Hardwood	50	45	36
	Herbaceous	60	90	75
	LEVEL 2 TOTALS	282	295	258
LEVEL 3	Perennial Agriculture	41	32	41
	Annual Agricuture	76	97	88
	Conifer	38	40	40
	Douglas Fir	23	22	25
	Aspen	32	32	32
	Cottonwood	17	18	18
	Willow	23	21	20
	Sage Grassland	21	21	21
	Grassland	19	19	19
	LEVEL 3 TOTALS	303	202	290

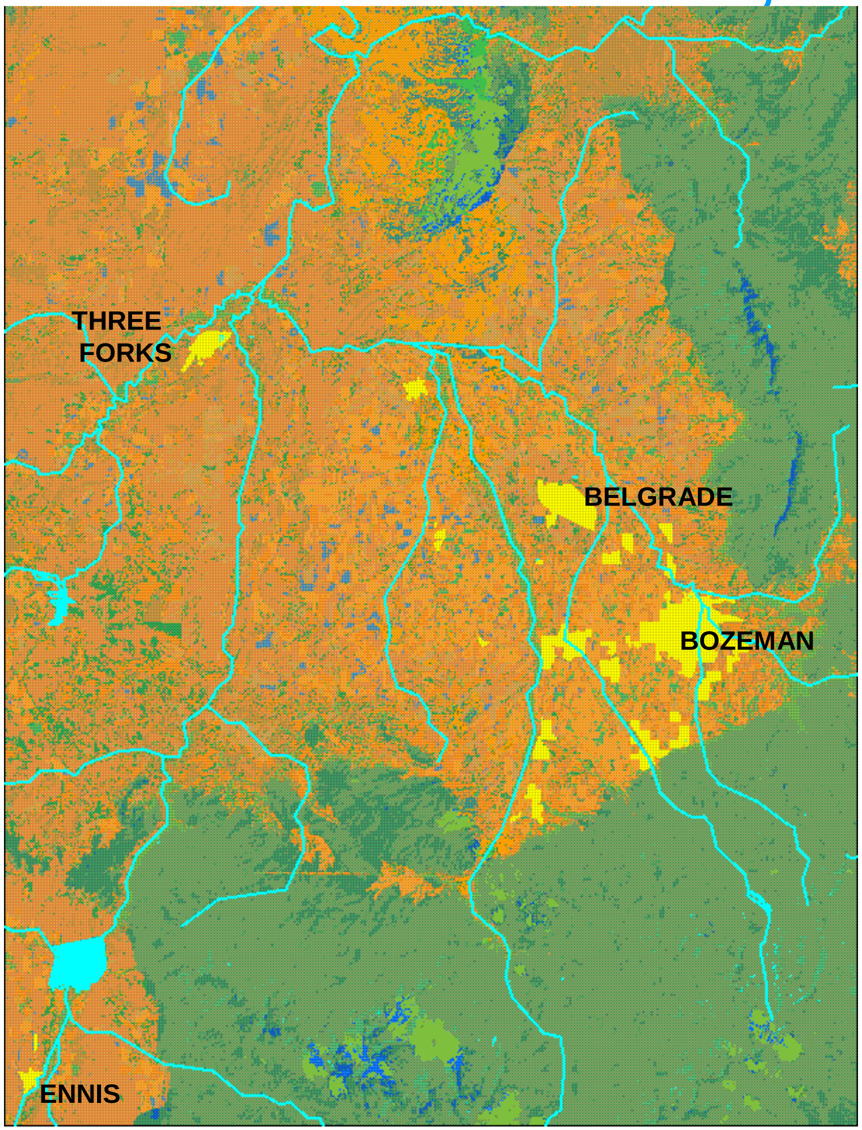
Classification Methods

- **1. Extract Explanatory-variable Data:** for each reference data point.
- **2. Develop CART Rules:** for each classification level and cover type using reference and explanatory data (32 variables).
- **3. Apply Rules:** create a classified map for each level.
- **4. Evaluate Accuracy:** use independent validation data
- **5. Extrapolate:** apply classification rules across the GYE for all years, all levels

25-Year History - Land Cover

Preliminary Classification Results

Pilot 1, Level 1, 1994



User's Accuracies for Level 1

AGRICULTURE	84%
NON-VEG	75%
NATURAL VEG	97%

Overall Classification Accuracy = **91%**

Agriculture

Natural Vegetation

Non-Veg (Soil and Rock)

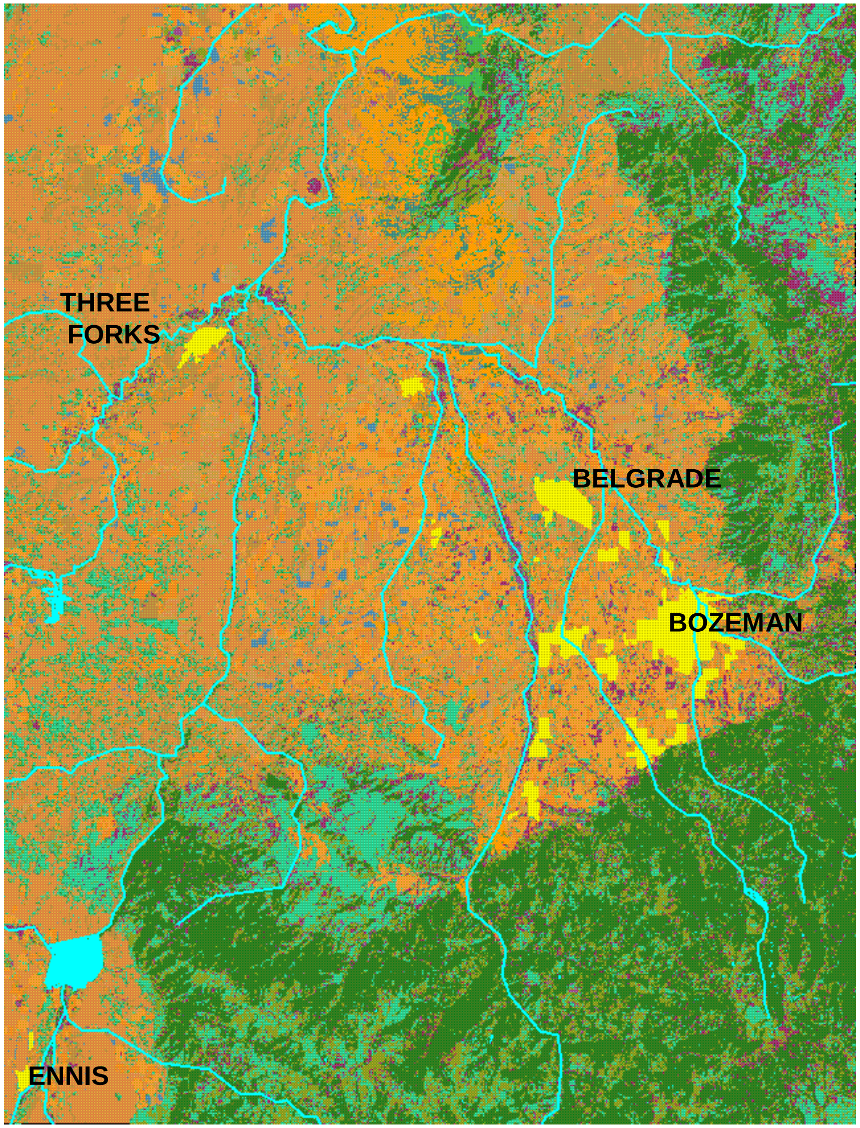
Water

Urban

25-Year History - Land Cover

Preliminary Classification Results

Pilot 1, Level 2, 1994



User's Accuracies for Level 2

CONIFER	87%
HERBACEOUS	70%
HARDWOOD	73%

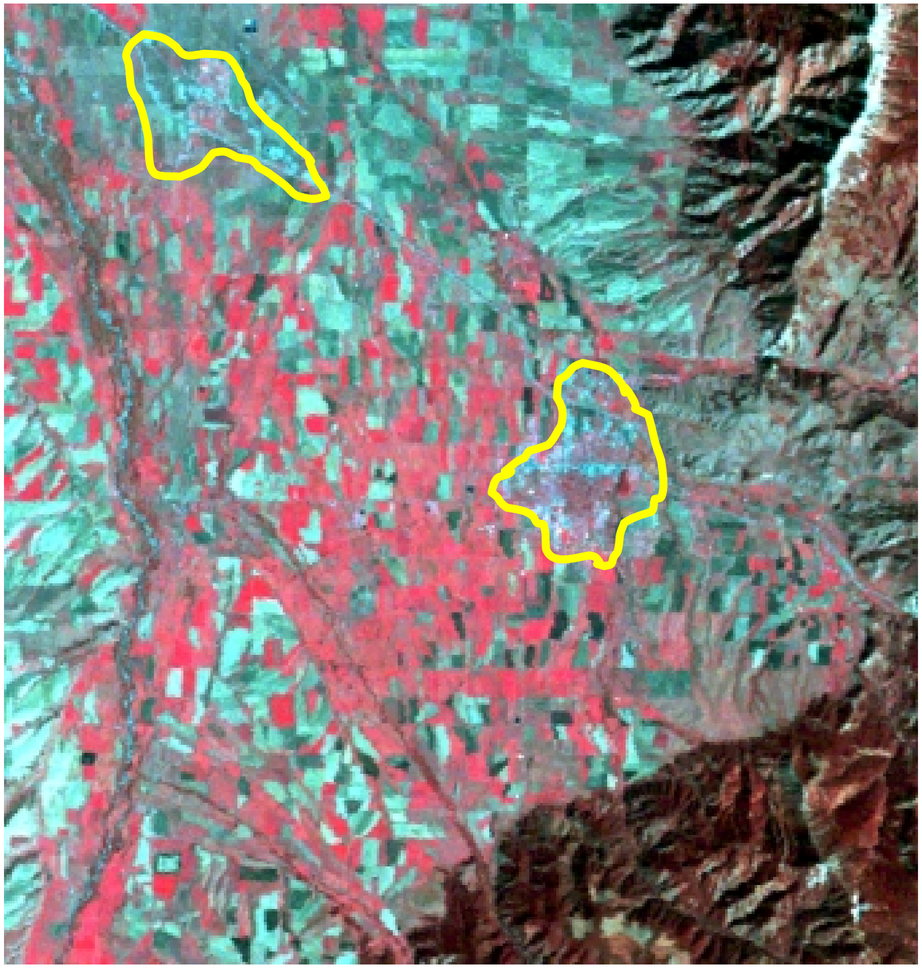
Overall Classification Accuracy = **76%**

Level 1	**Level 2**
Agriculture	**Conifer**
Non-Veg	**Herbaceous**
Water	**Hardwood**
Urban	**Mixed Conifer-Herb**
	Mixed Hardwood-Herb

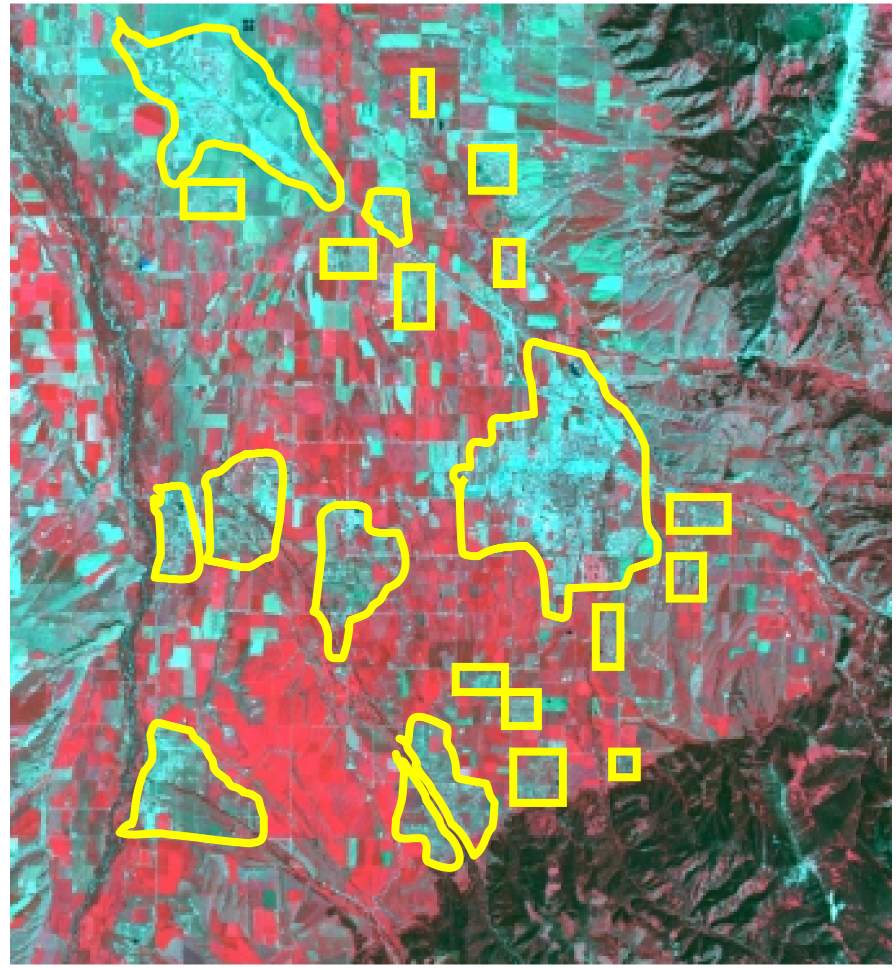
Change Detection

- Method 1: Traditional Difference Approach
- Method 2: Cohen Difference Threshold Approach
- Compare Methods 1 and 2 and use best.

Change:Gallatin Valley, MT



1976
MSS Imagery 4-2-1



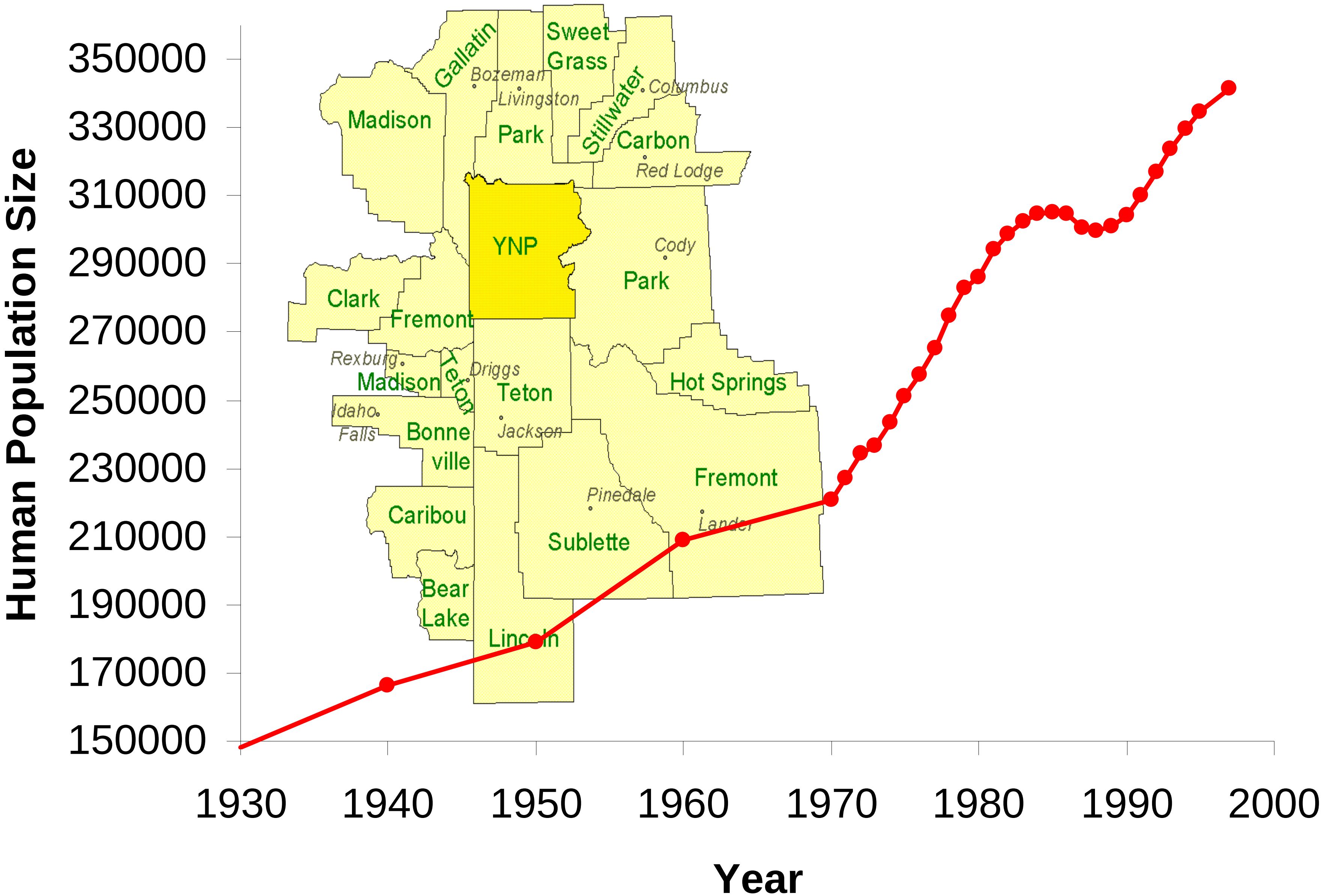
1994
TM Imagery 4-3-2

Land Cover Classification: Status

Task	Area			
	Pilot 1	Pilot 2	Pilot 3	GYE
Develop methods	X	X	X	X
Acquire imagery	X	X	X	X
Obtain reference and predictor data	X	X		
Classify and Validate	X			
Detect Change				

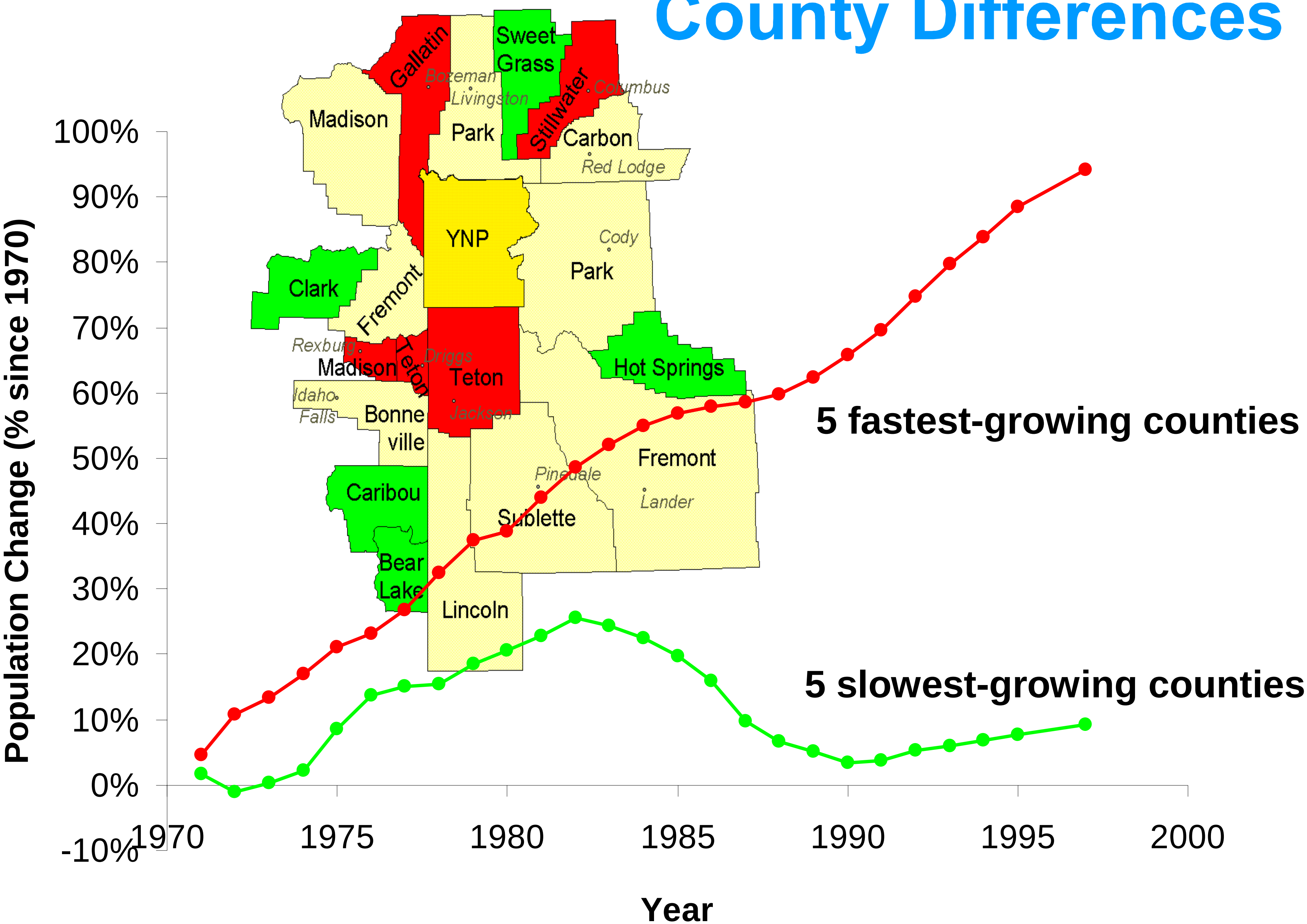
25-Year History

Human Demography - GYE-Wide



25-Year History

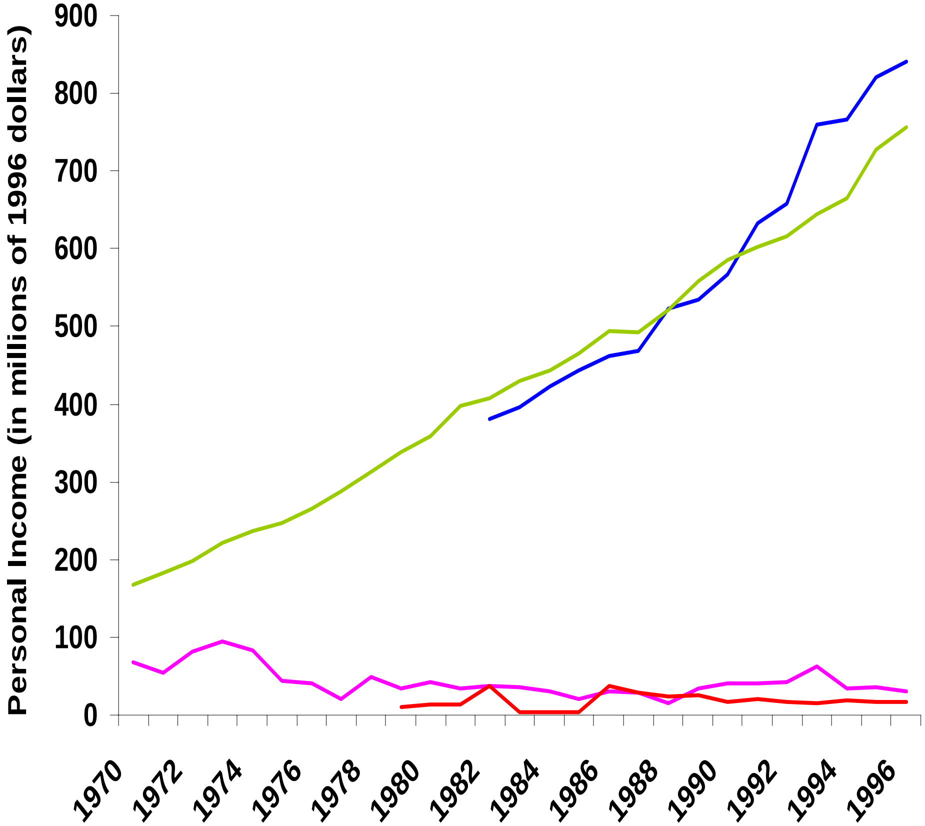
County Differences



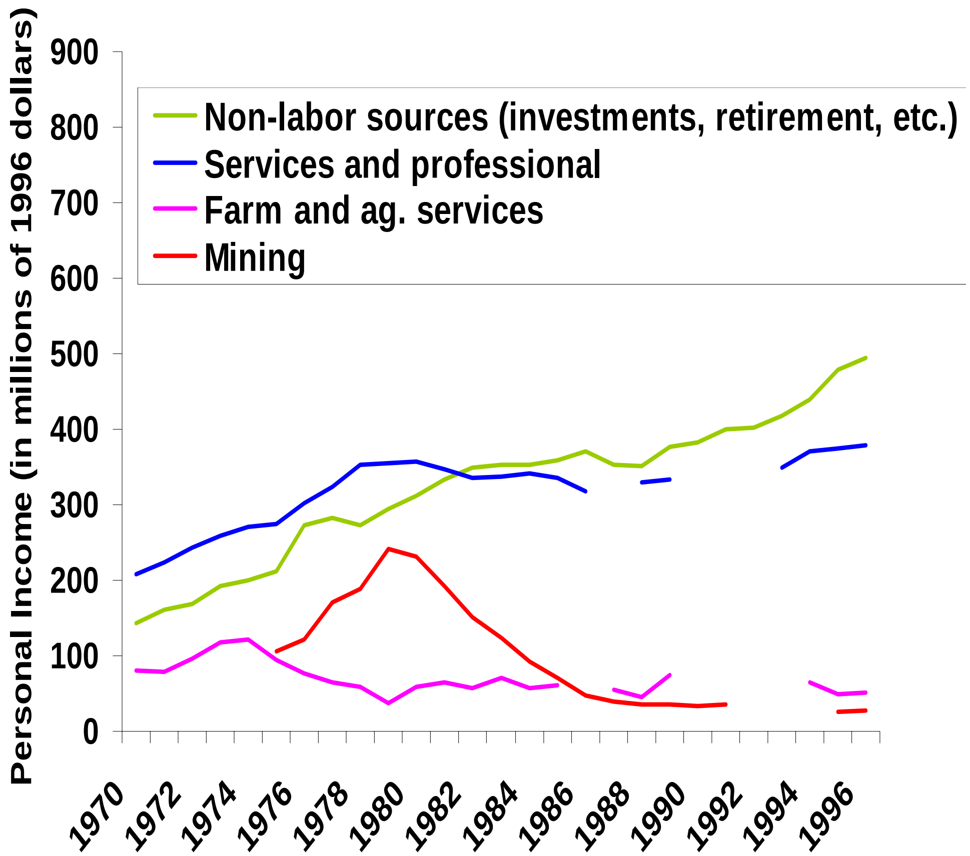
25-Year History

Economic Trends: County Differences

Four Fastest Counties

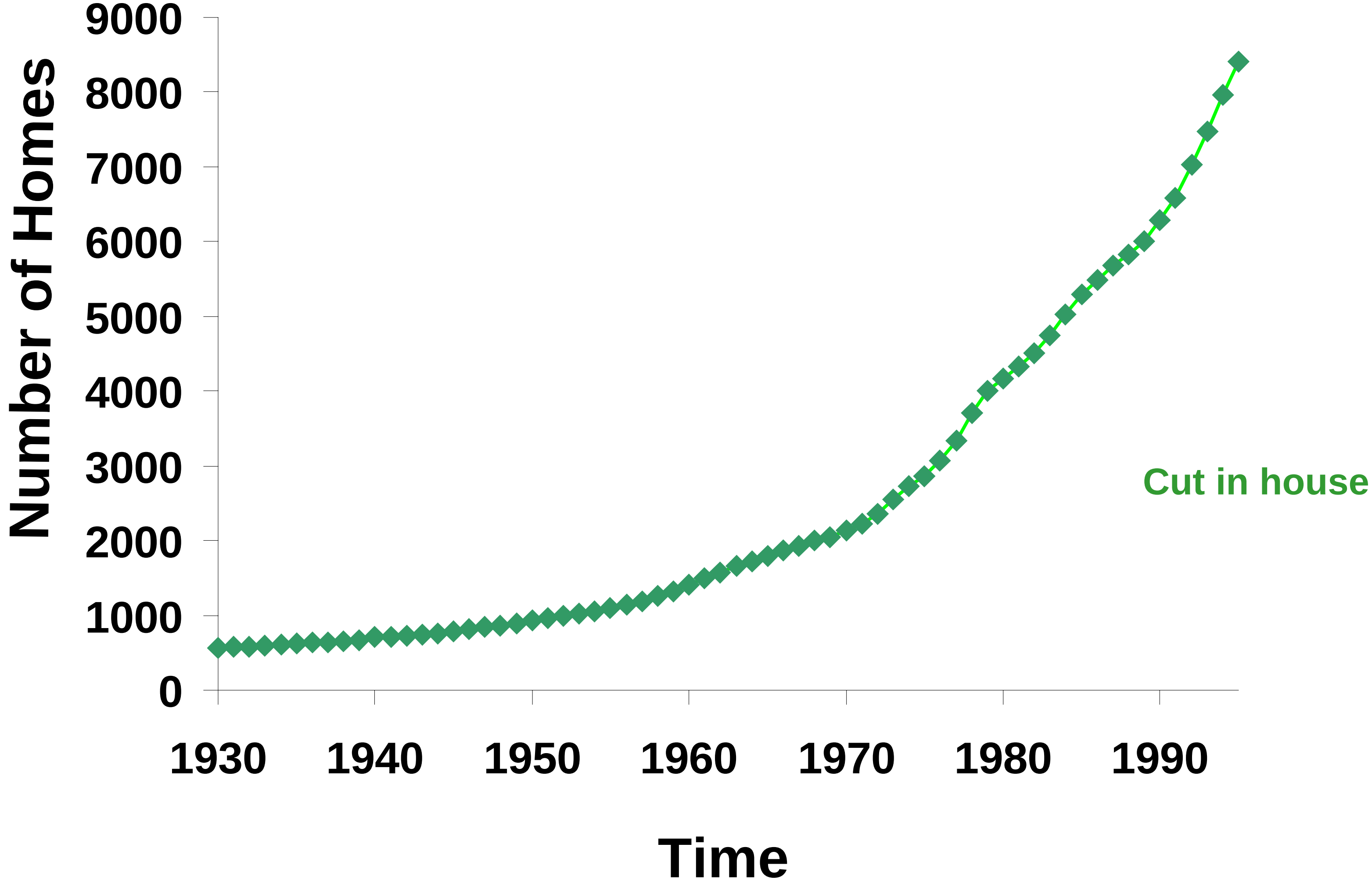


Four Slowest Counties



25-Year History

Rural Residential Development: Gallatin Co, MT



25-Year History: Status

Task	Topic			
	Demo-graphy	Economic	Social	Biodiversity
Obtain data	X	X	X	
Analyze data	X	X		
Prepare publications				

Expected Products:

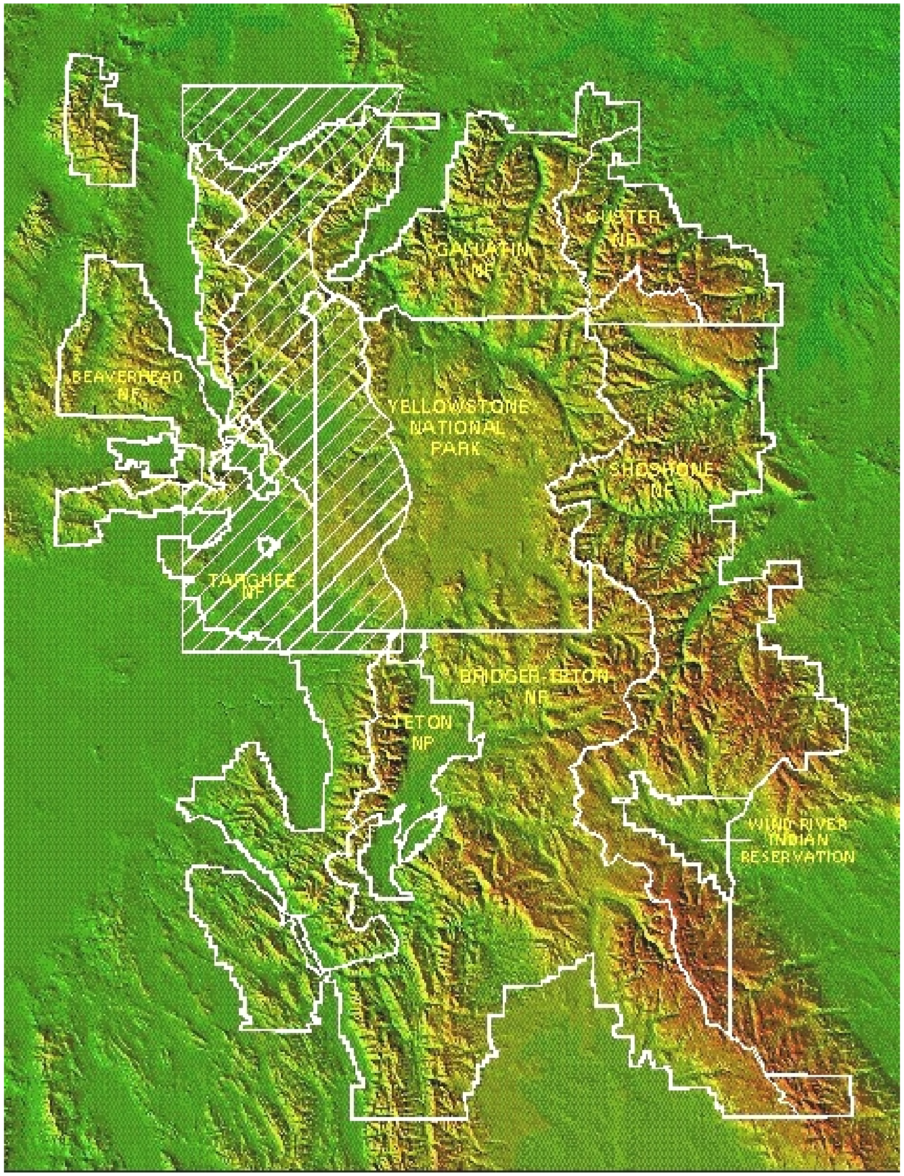
•**Hansen et al. Twenty-five year history of the Greater Yellowstone Ecoystem. (2000).**

Objective 2: Hypotheses

- H1: Abiotic factors cause NPP to be low and variable over most of the GYE.
- H2: Biodiversity is correlated with abiotic gradients and NPP and is high only in hot spots.
- H3: Human land use is most intense near hot spots.
- H4: Socioeconomic performance is influenced by ecological factors.
- H5: Intense land use reduces the population viability of some native species.

Obj 2: Hypothesis testing

SPATIAL PATTERNS OF NPP



Hypothesis 1:

Patchy topography, climate, and soil cause NPP to be low and variable over most of the GYE.

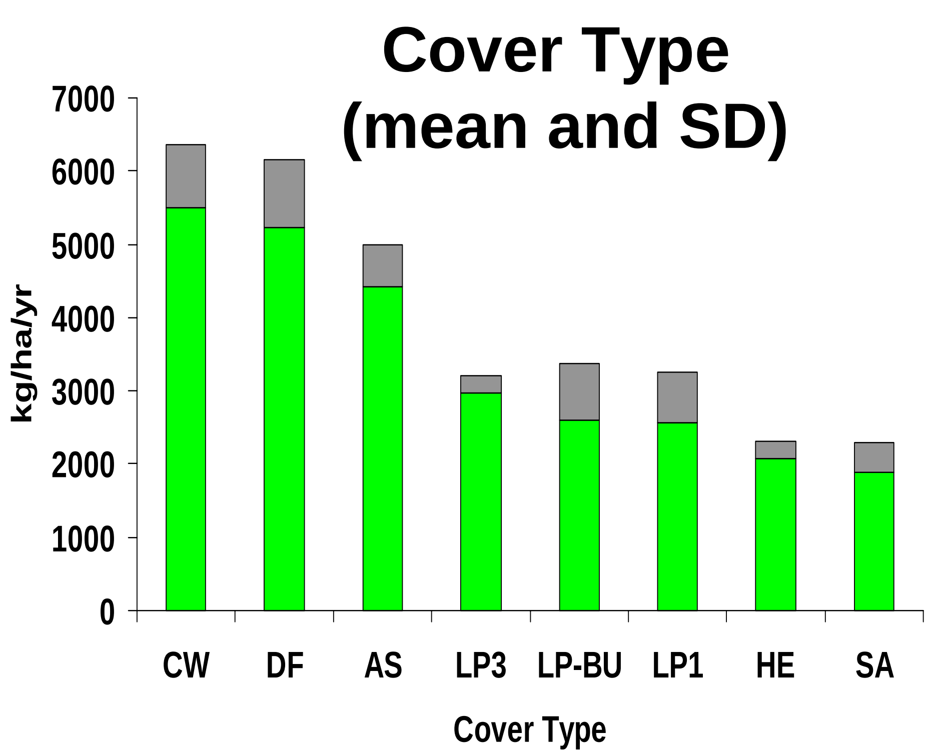
Methods

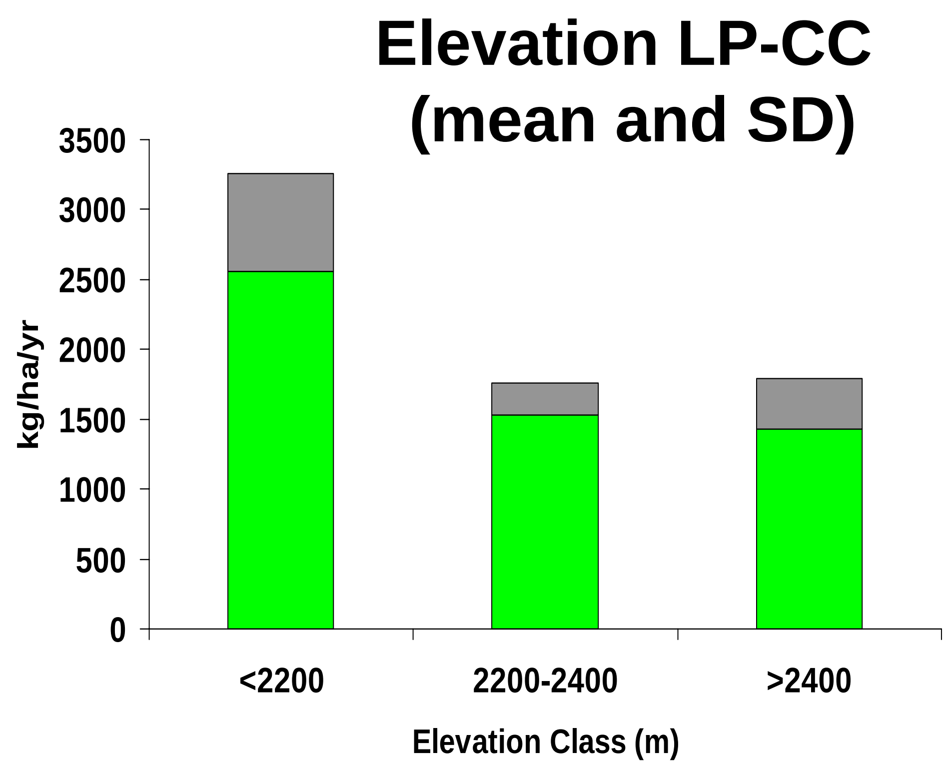
- Select field sites (100) stratified over biophysical gradients.
- Collect data on vegetation dimensions and growth rates.
- Use allometric relationships to predict biomass change/year.
- Extrapolate ANPP from sites to study area.
- Analyze spatial patterns of ANPP.

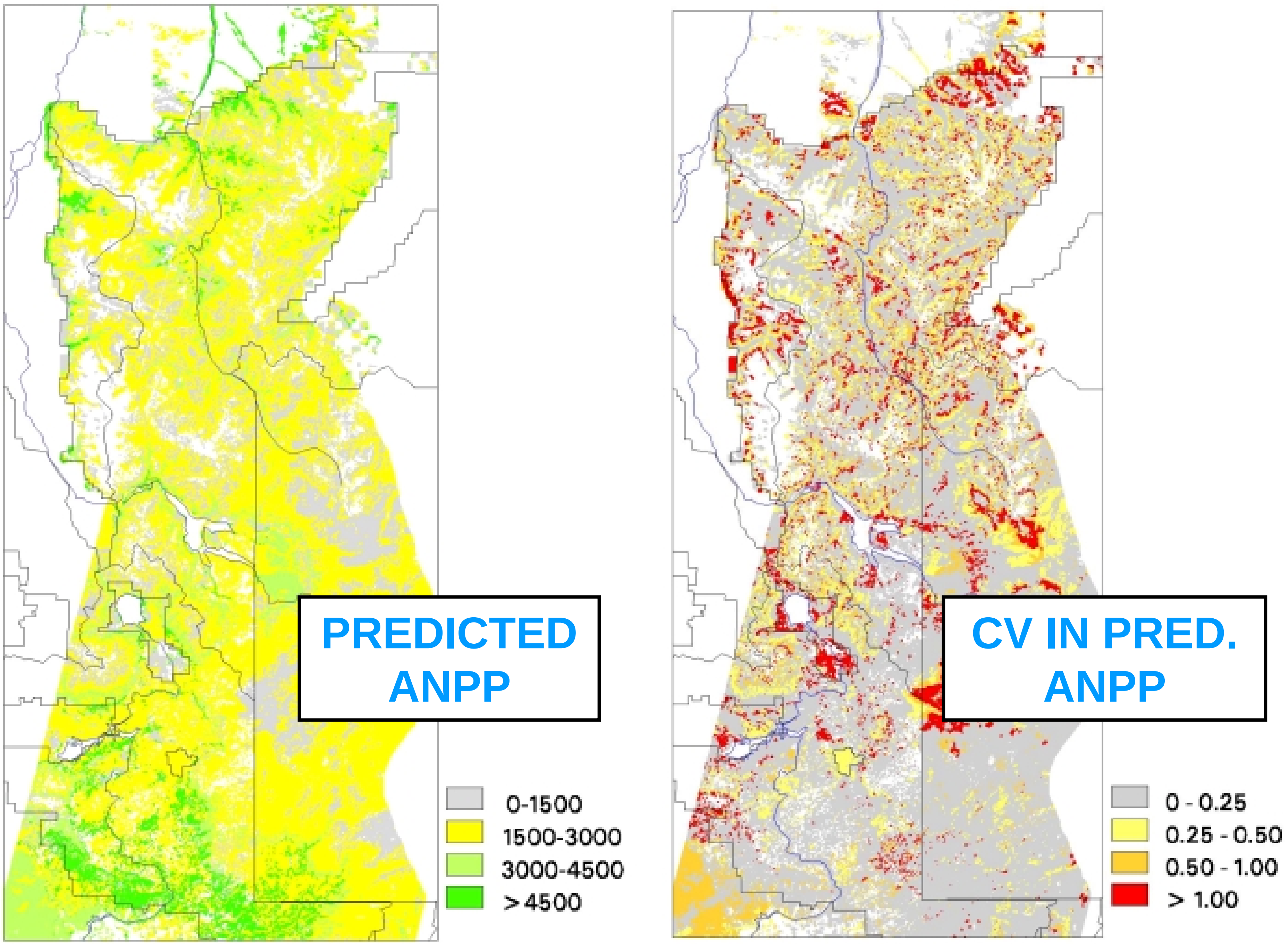
Results

- **<u>Predictor variables evaluated</u>: elevation, slope, aspect, specific catchment area, parent material, cover type.**

- **Best Model: ANPP = cover type, elevation, interaction (R^2=.89, P<.0001).**







PREDICTED ANPP
0-1500
1500-3000
3000-4500
> 4500
CV IN PRED. ANPP
0 - 0.25
0.25 - 0.50
0.50 - 1.00
> 1.00

SPATIAL PATTERNS OF BIODIVERSITY

Hypothesis 2:

Strong abiotic gradients (topography, climate, soil) cause native species abundances and richness to be high only in localized hot spots across the landscape.

Methods

- Select field sites (100) stratified over biophysical gradients.
- Collect data on abundance of bird, shrub, and tree species.
- Extrapolate species abundances and richness from sites to study area.
- Analyze spatial patterns of biodiversity.

PREDICTOR VARIABLES

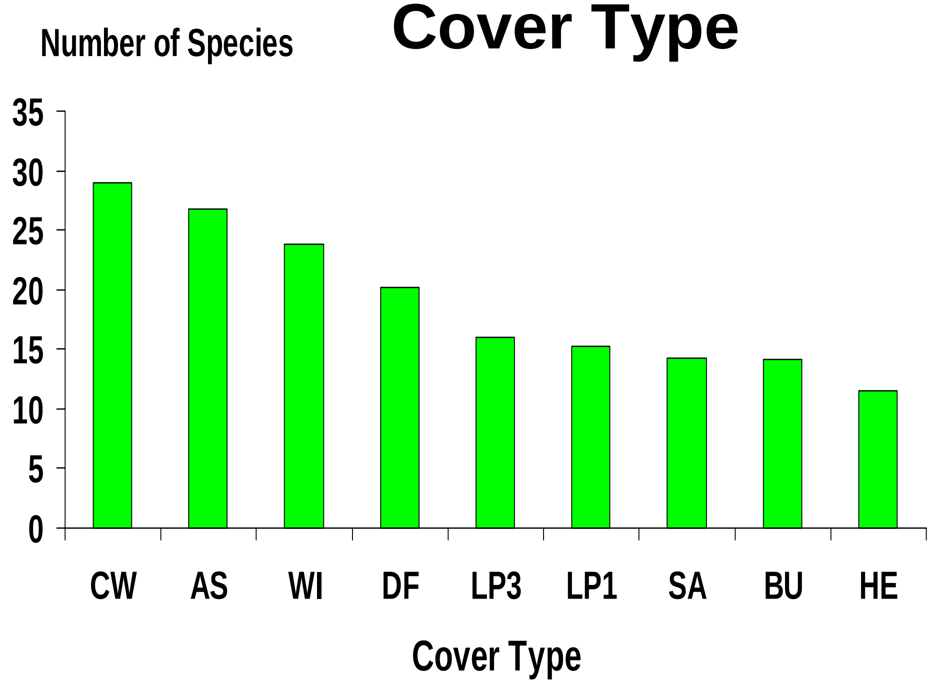
Theme	Source	Methods
Elevation, Slope, Aspect	USGS DEM	Derive from DEMs
Specific Catchment Area	DEM and	Derive with Arc-Info Watershed Function
Monthly Temp., Monthly Precip., Snow-melt Date	Met Stations	Regressed based on elevation and/or latitude. Averaged over 1995-97
Parent Material Type	Soils Maps	Soil types grouped into parent material classes
Vegetation Cover Type	Field	Simple cover type classification
Vegetation Structure	Field	Structural complexity indicies developed from field data
ANPP	Field	Total, deciduous, and coniferous ANPP developed with BIOPAK and field data.

Results: Bird Richness

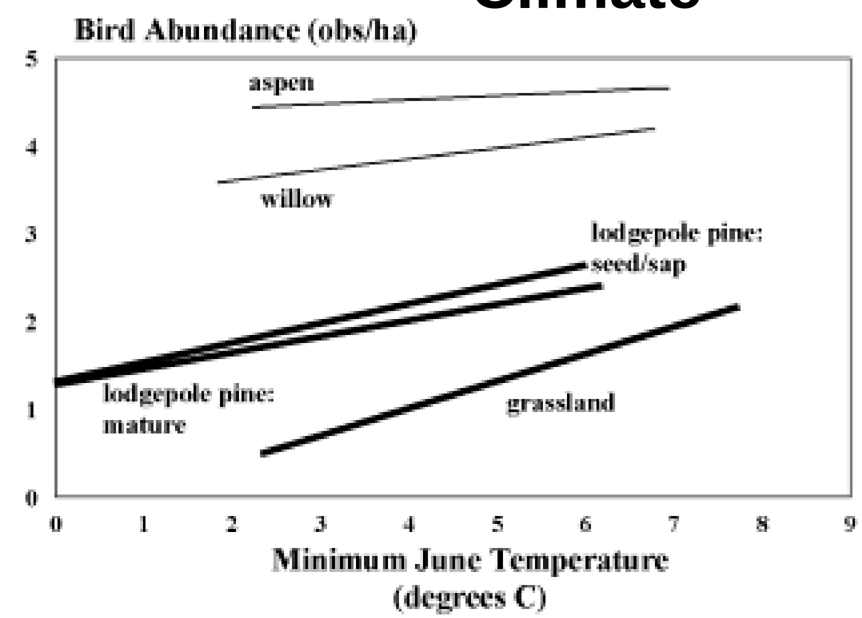
- **<u>Predictor variables evaluated</u>: elevation, slope, aspect, parent material, climate (6 variables), veg structure, ANPP, cover type.**

- **Best Model: Richness = cover type, climate, parent material (R^2=.89, P<.0001).**

Cover Type

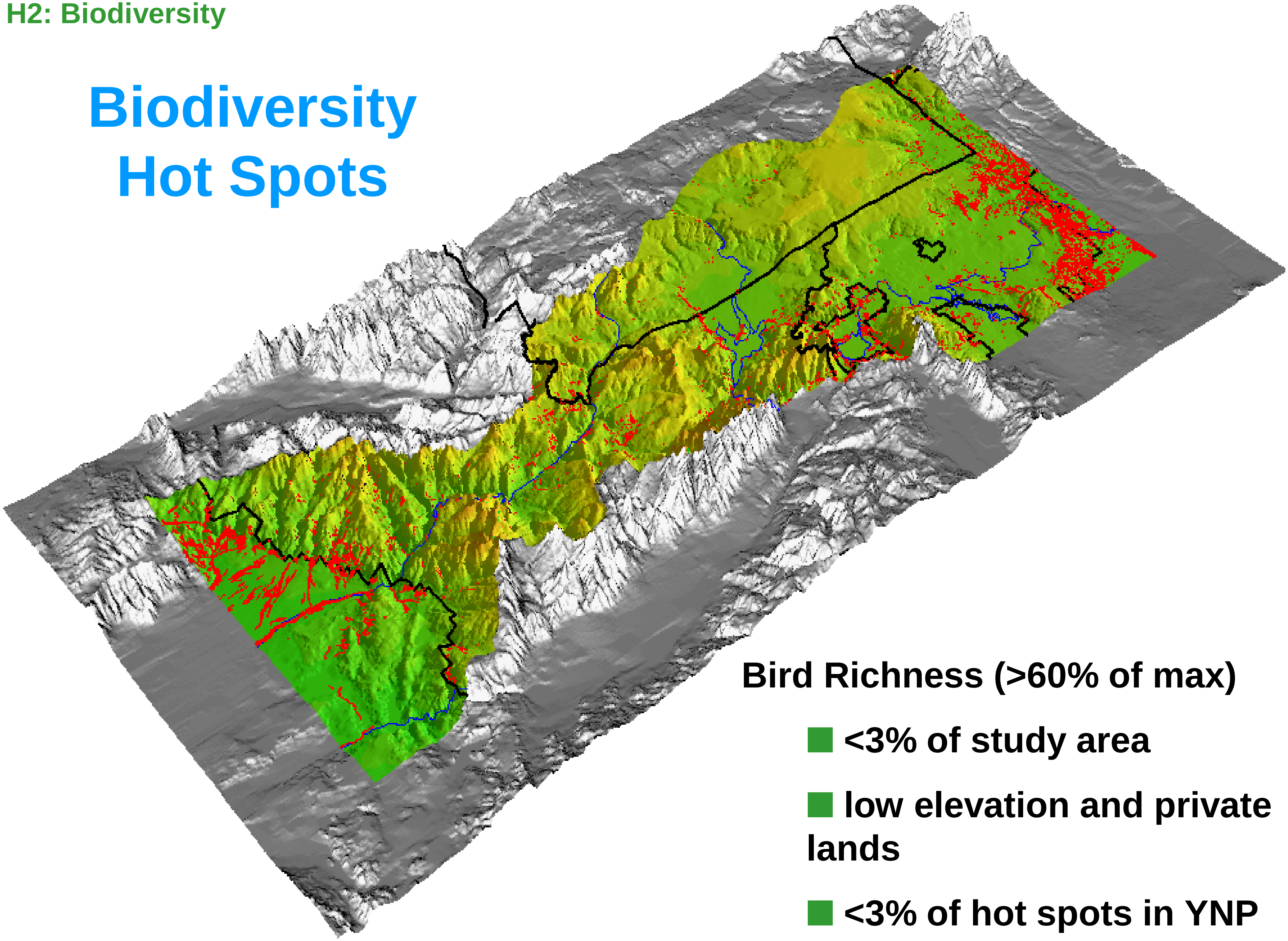


Climate



H2: Biodiversity

Biodiversity Hot Spots



Bird Richness (>60% of max)

- <3% of study area
- low elevation and private lands
- <3% of hot spots in YNP

Human Settlement and Biodiversity

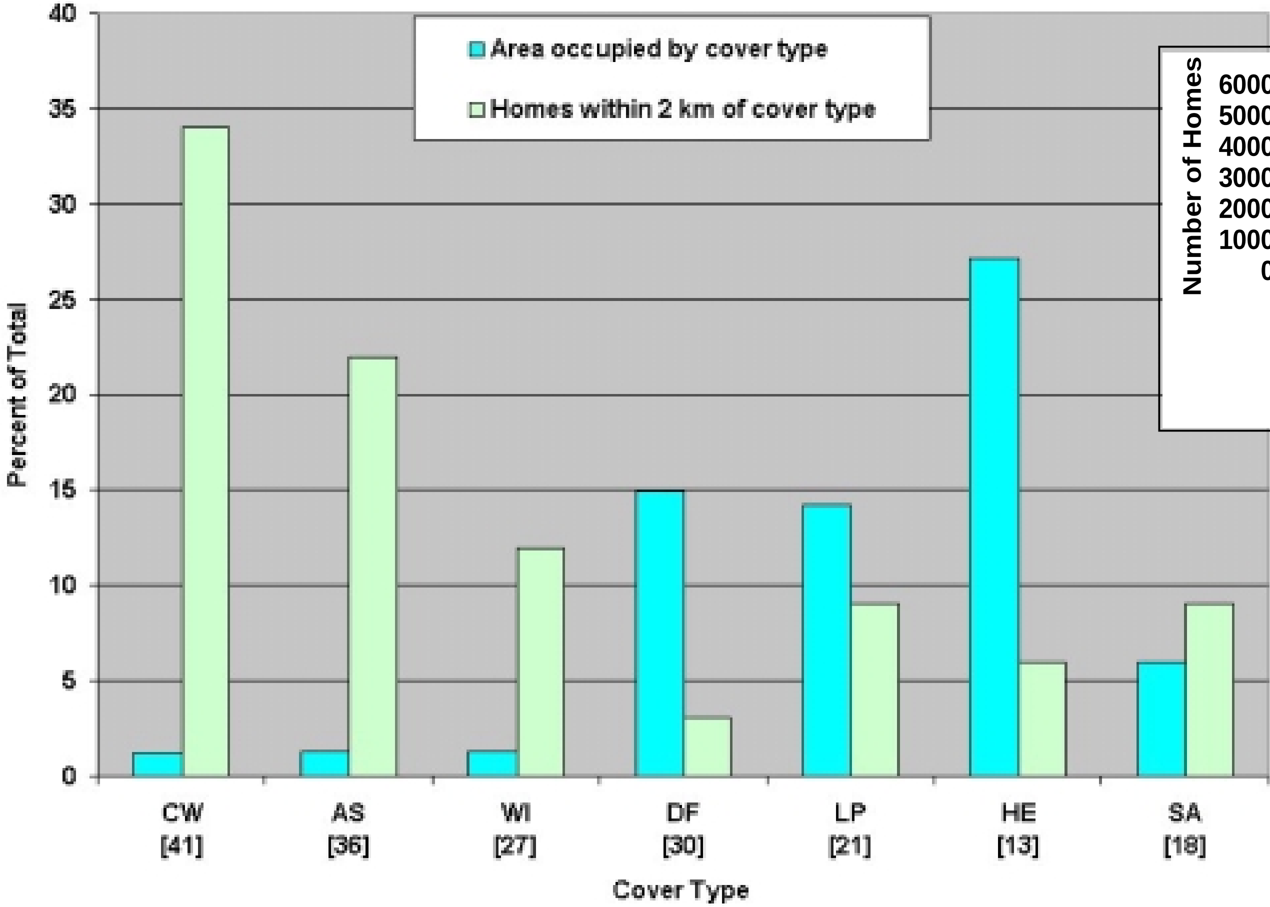
Hypothesis 3:

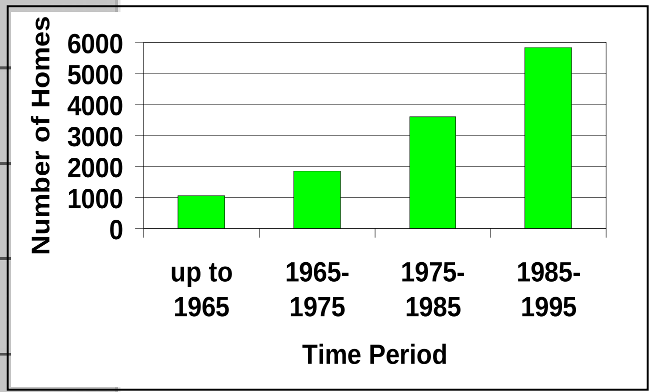
Human land use is correlated with environmental gradients such that land use is most intense at hot spots for biodiversity.

Methods

- Obtain home locations from sewer and well records, aerial photos, and field survey.
- Analyze spatial distribution relative to ecological, social, economic factors.
- Evaluate causes of home location from home-owner surveys.

Preliminary Results





Distribution of Homes Relative to Cover Types

Socioeconomic Performance and Biodiversity

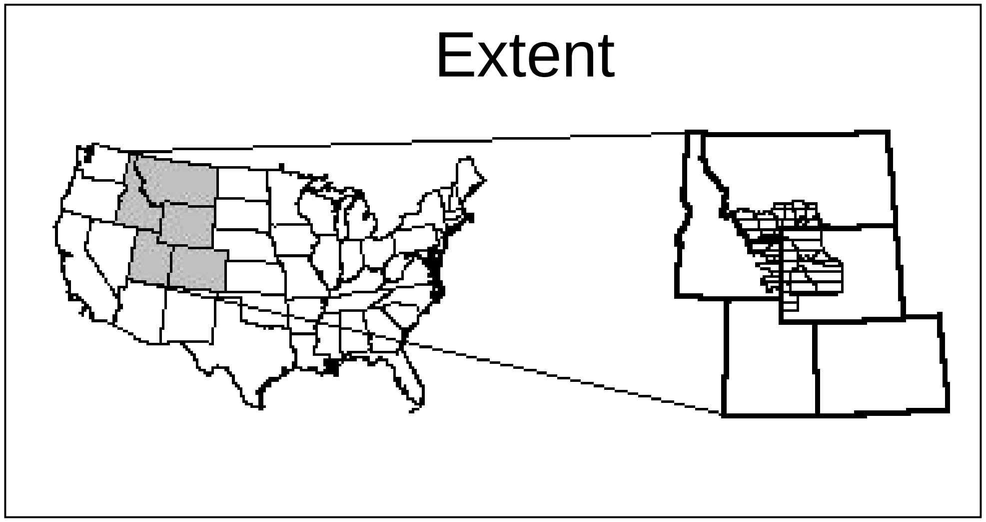
Hypothesis 3:

Population and income growth are associated with both socioeconomic and ecological factors .

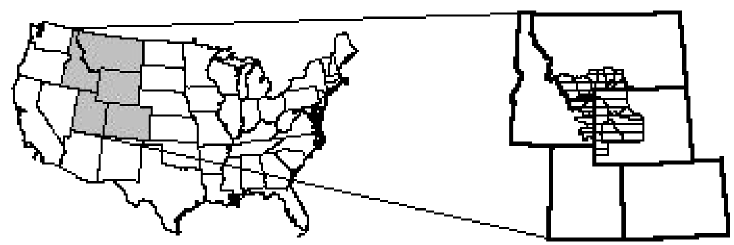
Methods

socioeconomic performance = f(x_1, x_2, ….. X_n)

x_1 = ecological factors (topography, soils, water, climate, vegetation, biodiversity)
x_2 = education
x_3 = justice
x_4 = commerce
x_5 = transportation
x_6 = health
x_7 = recreation



Results: Rocky Mountains



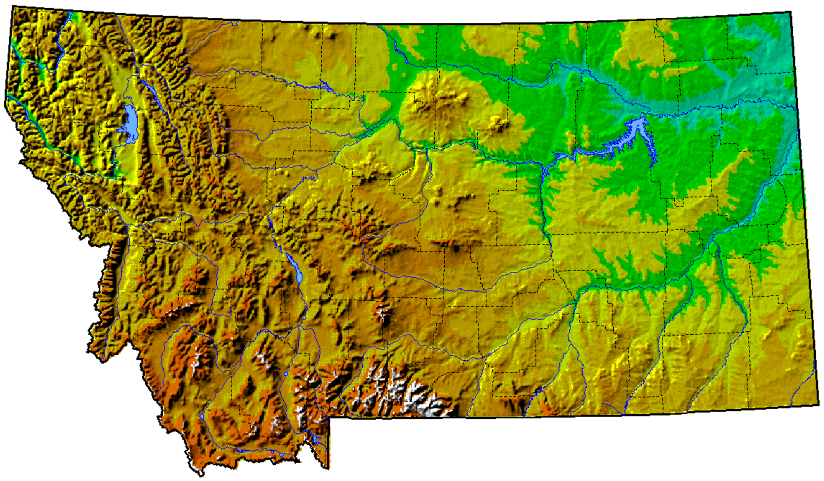
- 87% of income growth in services (especially producer) and nonlabor sectors.

- Extractive industries had only 2% of new income.

- Rural counties with high socioeconomic performance are characterized by growth in producer services. e.g., Aspen, Co., Telluride, Co., Vail, CO., Bozeman, MT., Sun Valley, ID.

- Correlates with "producer service" counties: college ed (% of pop.) and airport service. Not proximity to wilderness, national park, wildlife refuge.

Results: Montana



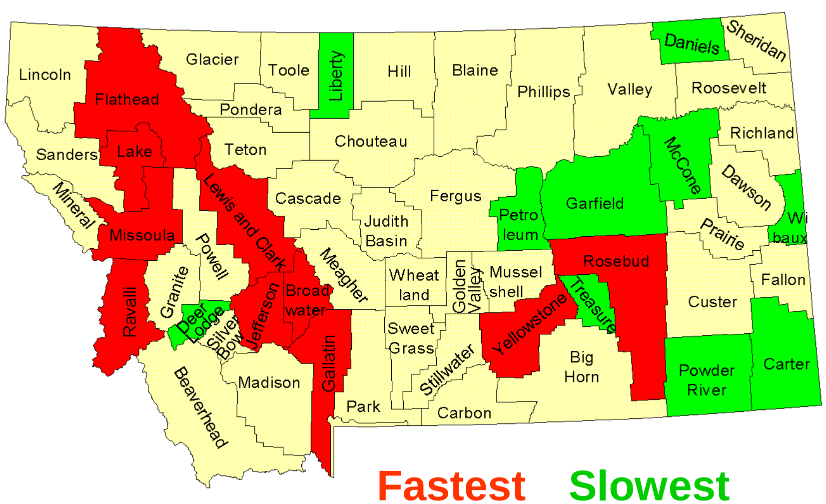
Potential Predictors

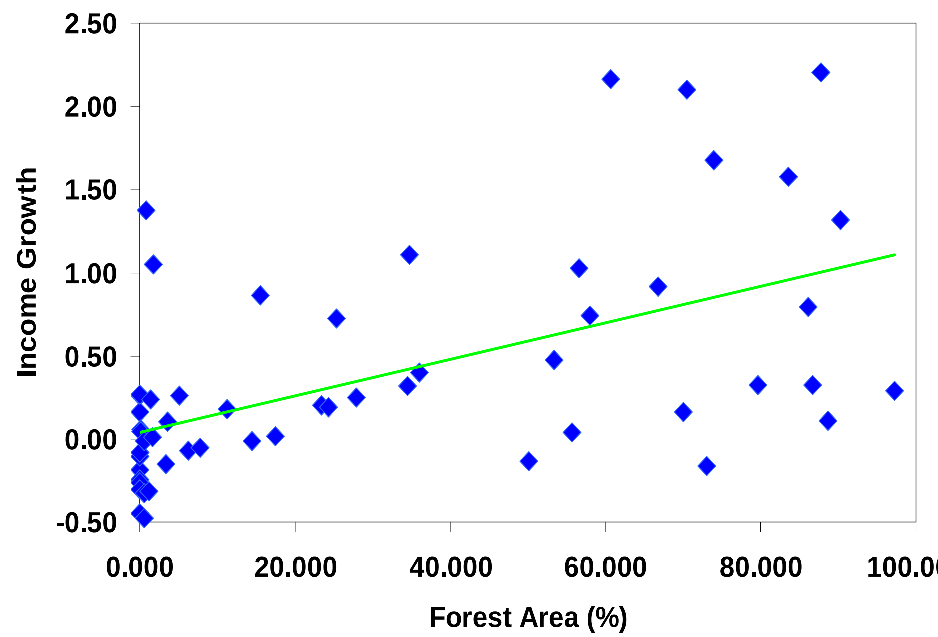
elev ppt temp forest reserves, streams, lakes

Best Model

forest tempsd tempm

R^2=.41 P<.001





Land Use Effects on Species Viability

Hypothesis 5:

Intense land use reduces the population viability of some native species.

Methods

- Locate nests in hot-spot and extensive habitats.
- Monitor reproductive success.
- Analyze data to determine vital rates and association with land use.
- Simulate population growth and probability of extinction.

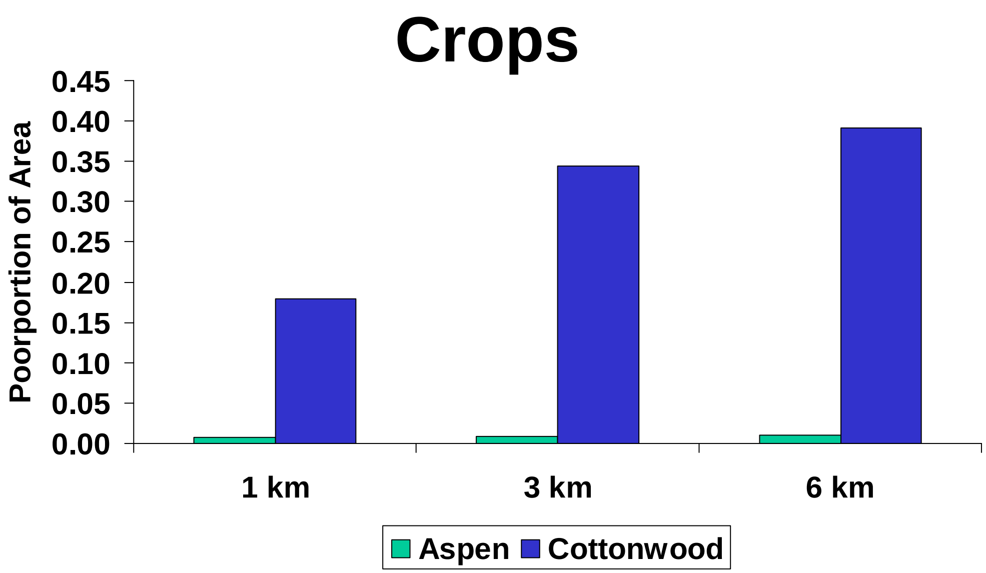
Results: Demography

Habitat	Nest Succ.	# Female Fledglings	Pop Growth Rate
AS	54%	0.81	1.13
LP	30%	0.44	0.90
CW	38%	1.32	0.94

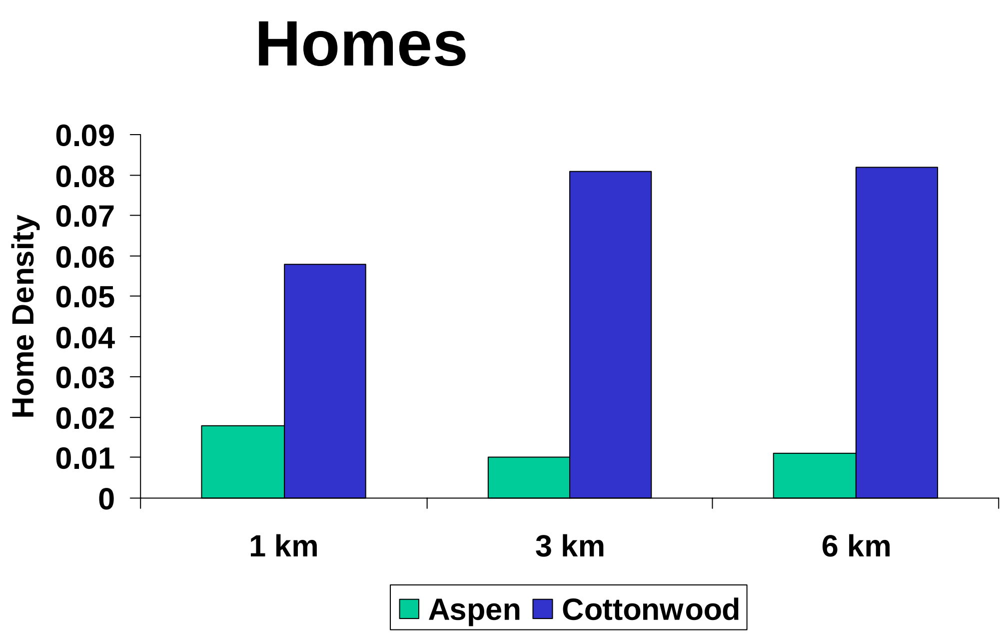
Open-Cup Nesters Vulnerable to Cowbirds

H5: Population Viability

Results: Land Use

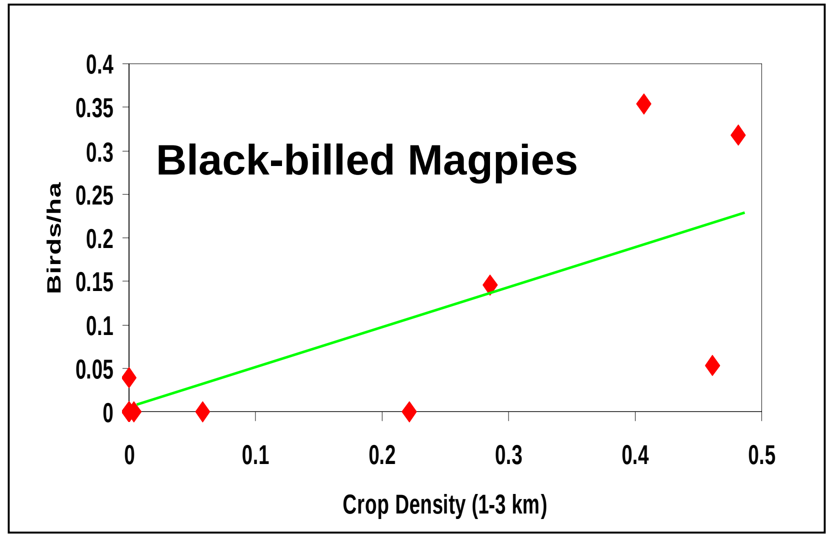


Proximity Homes, Crops, Cattle



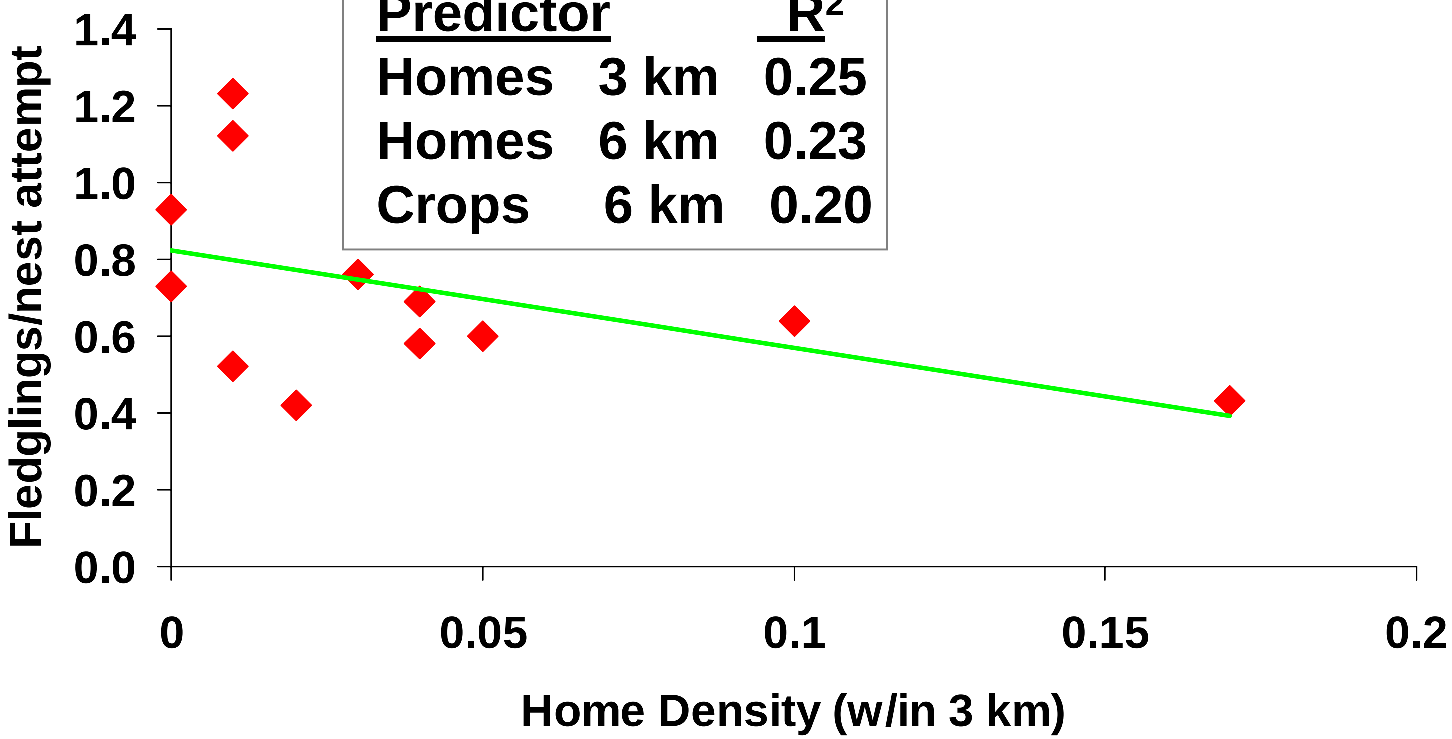
H5: Population Viability

Results: Land Use

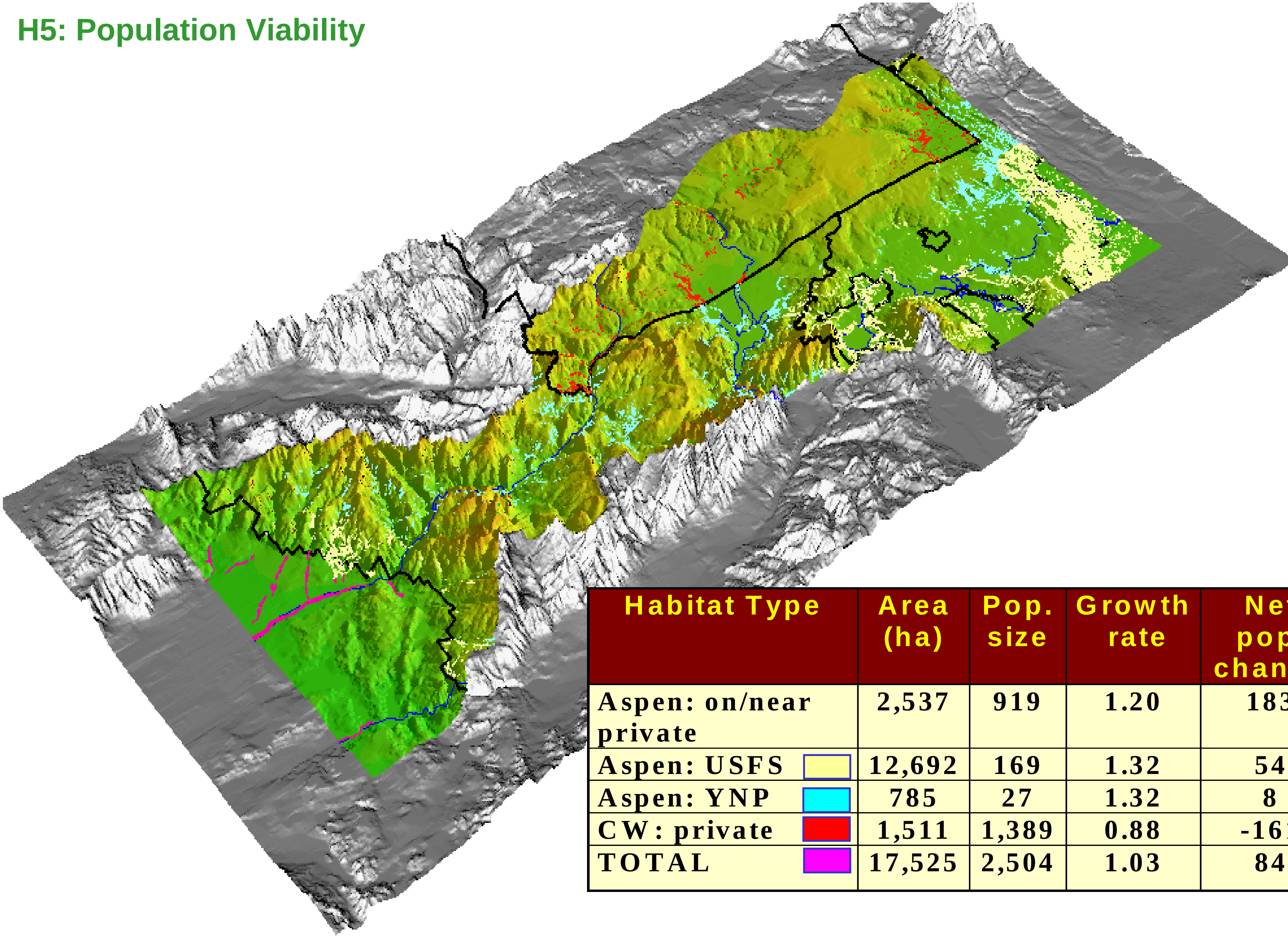


Reproductive Output

Predictor		R^2
Homes	3 km	0.25
Homes	6 km	0.23
Crops	6 km	0.20



H5: Population Viability



Habitat Type	Area (ha)	Pop. size	Growth rate	Net pop. change
Aspen: on/near private	2,537	919	1.20	183
Aspen: USFS	12,692	169	1.32	54
Aspen: YNP	785	27	1.32	8
CW: private	1,511	1,389	0.88	-161
TOTAL	17,525	2,504	1.03	84

Yellow Warbler Sources and Sinks

Objective 3: Risk Assessment

Approach

- Develop a systematic approach for identifying which species are most at risk of extinction and what places in the landscape are required by these species.
- Apply the approach to the current GYE landscape as a basis for conservation.
- Develop and apply a system to predict future land use on private lands.
- Assess biodiversity risk under the simulated future landscape.

Obj 3: Risk Assessment

DYNAMIC HABITAT AND POPULATION ANALYSIS

DEFINE PLANNING AREA:

Gap Analysis, Critical Ecosystems

FILTER SPECIES AND PLACES

Screen 1: Which species merit field study based on continental traits?

Screen 2: Which species and places merit demographic study based on local traits?

Screen 3: Which species and places are highest priority for conservation based on PVA?

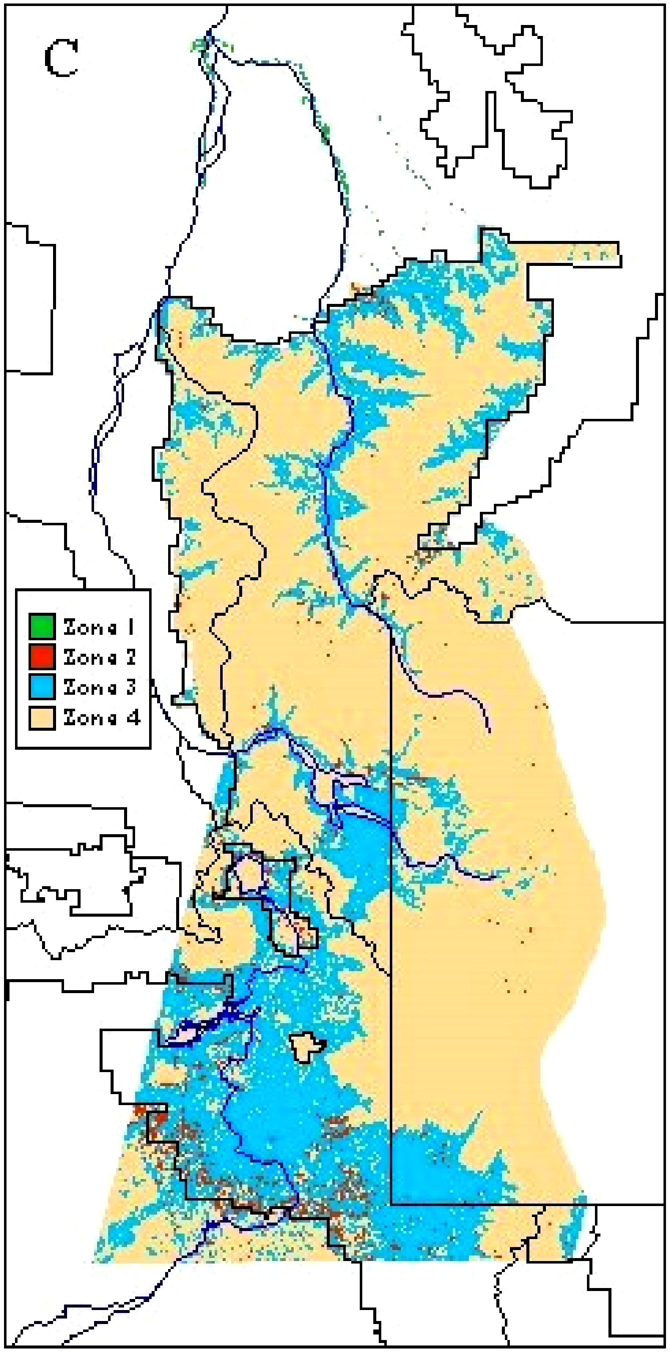
MANAGE:

Design, Implement, Evaluate Management Strategies

Examples of Species Deemed Most At Risk

- American redstart
- Willow flycatcher
- Veery
- Boblink
- Western woodpeewee
- Hammond's flycatcher
- Red-naped sapsucker
- Orange-crowned warbler
- Northern oriole
- Ruffed grouse
- Black-backed woodpecker

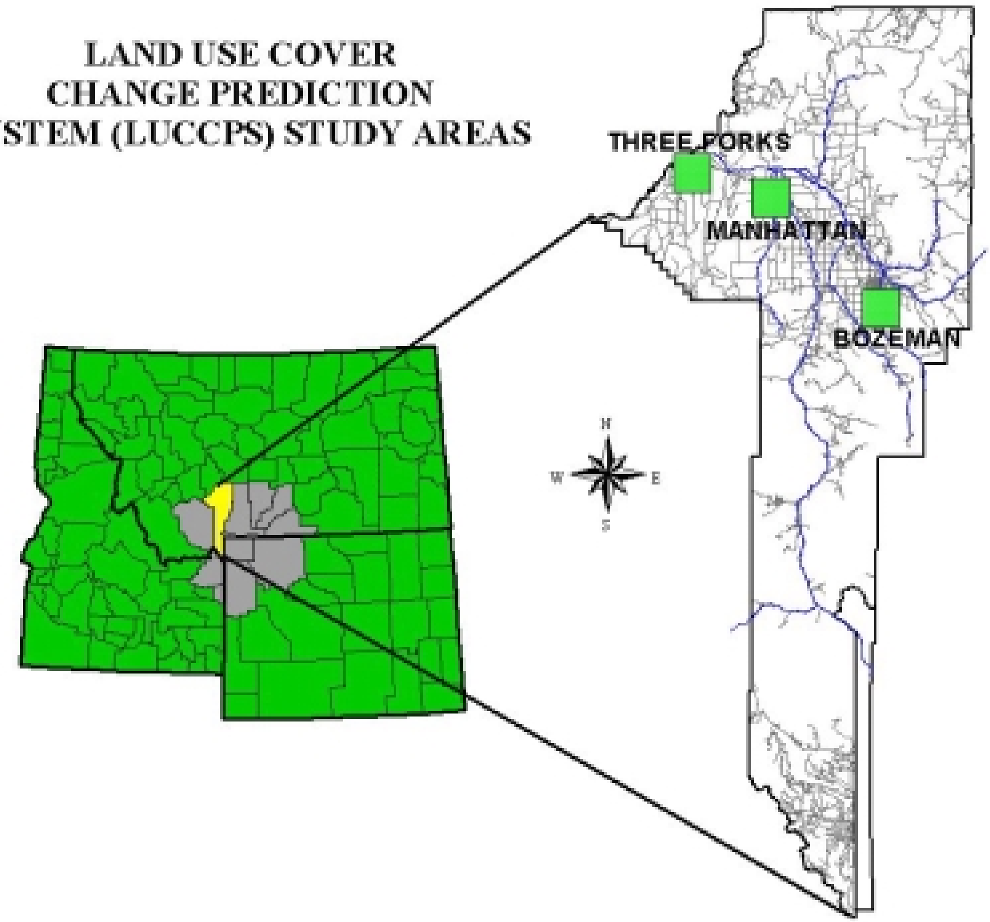
Obj 3: Risk Assessment



Example of Conservation Plan

Obj 3: Risk Assessment

Land Use Cover Change Change Prediction System (LUCCPS)



Obj 3: Risk Assessment

Land Use Change Model

Select study sites that maximize land use change, e.g. adjacent to communities

Classify Land Use/Cover on aerial photos of study site from several years

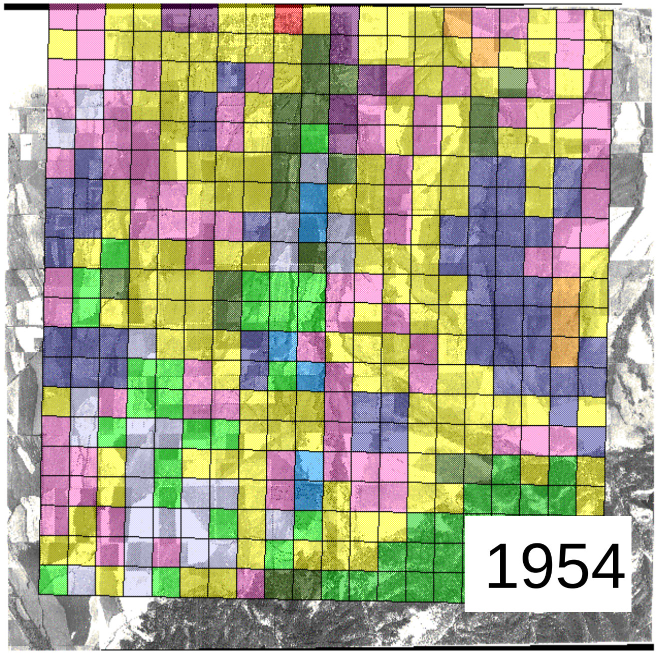
Develop and test a probability based, multidimensional transition matrix model to predict land use change

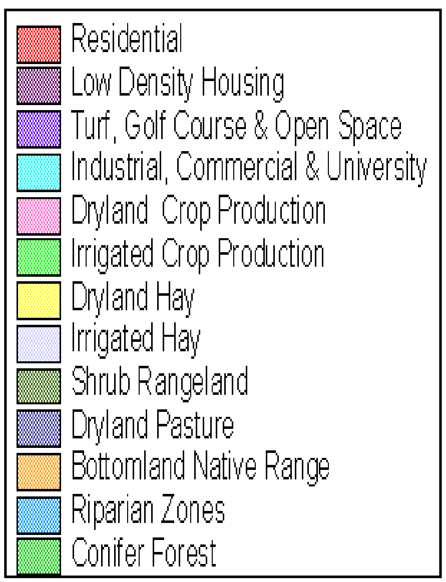
Identify data layers that can be added to the model to improve predictions

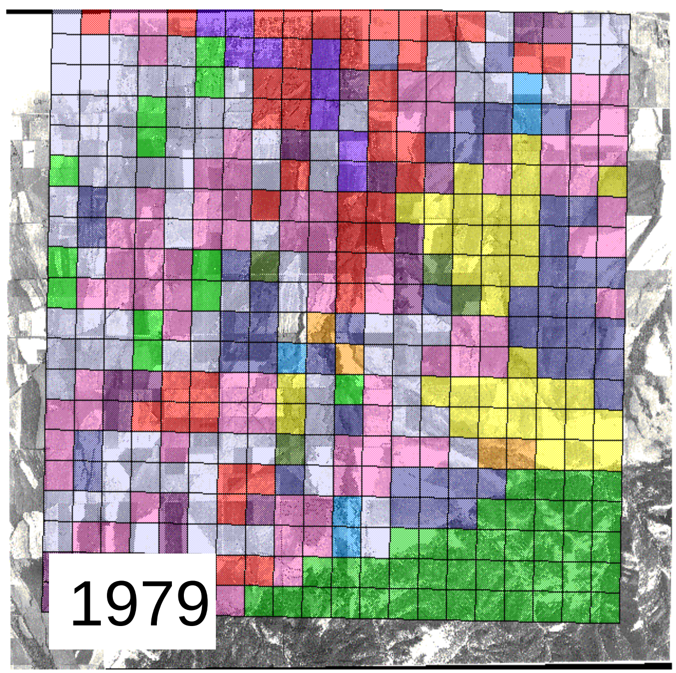
Use the model with land use/cover layers derived from remote sensed data to predict land use pattern dynamics on private lands around the GYE

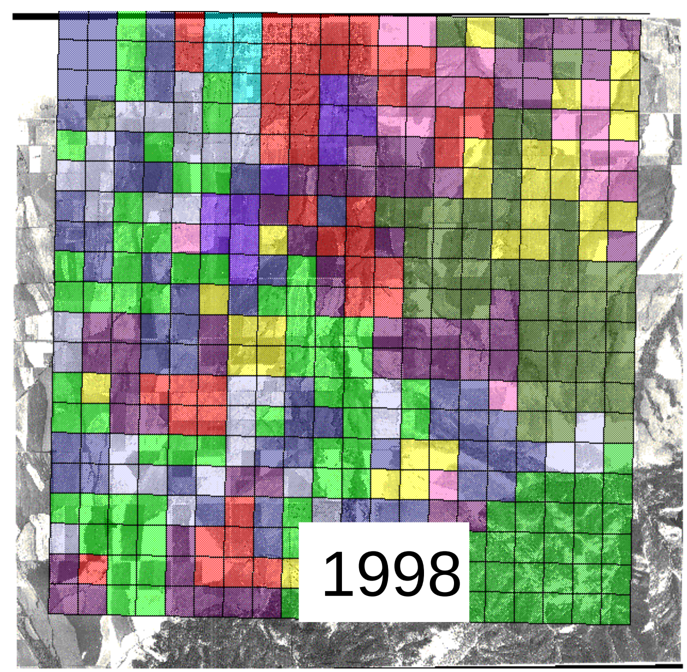
Associate predicted land use patterns with risk of biodiversity decline

Land Use Change : Bozeman, MT.



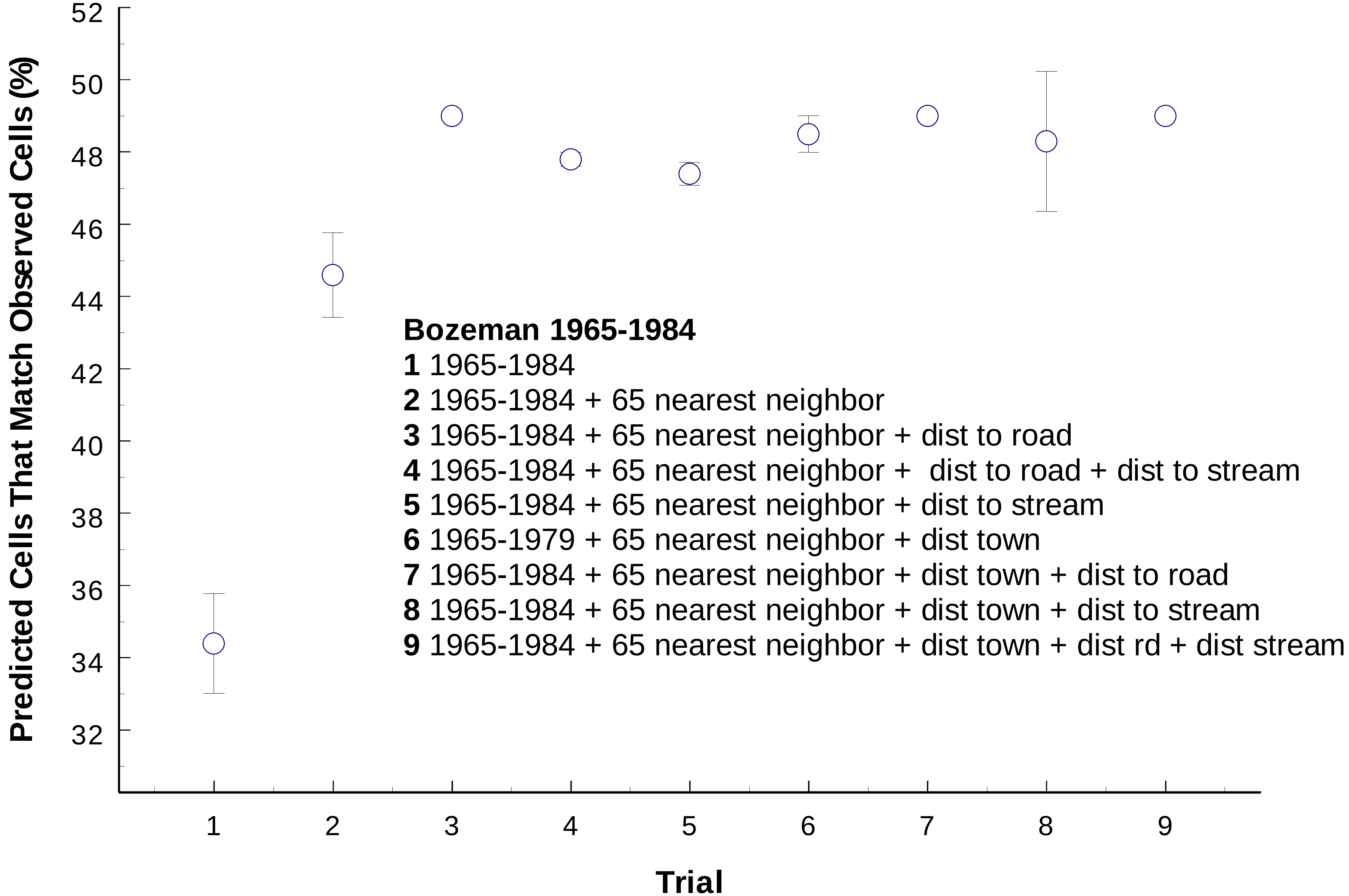






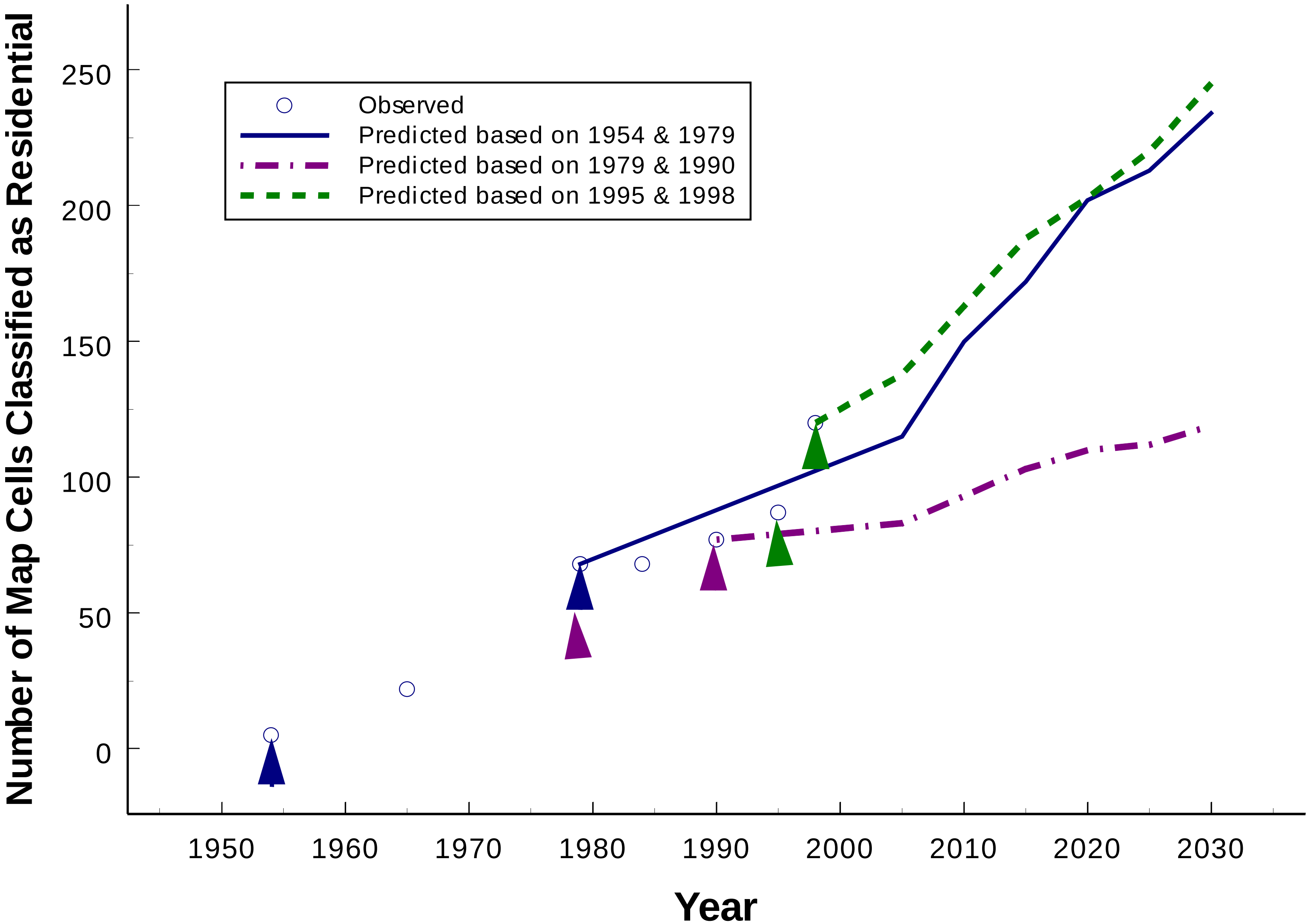
Obj 3: Risk Assessment

Modified Transition Probabilities



Obj 3: Risk Assessment

Predictions of Residential



Objective 4: Monitoring

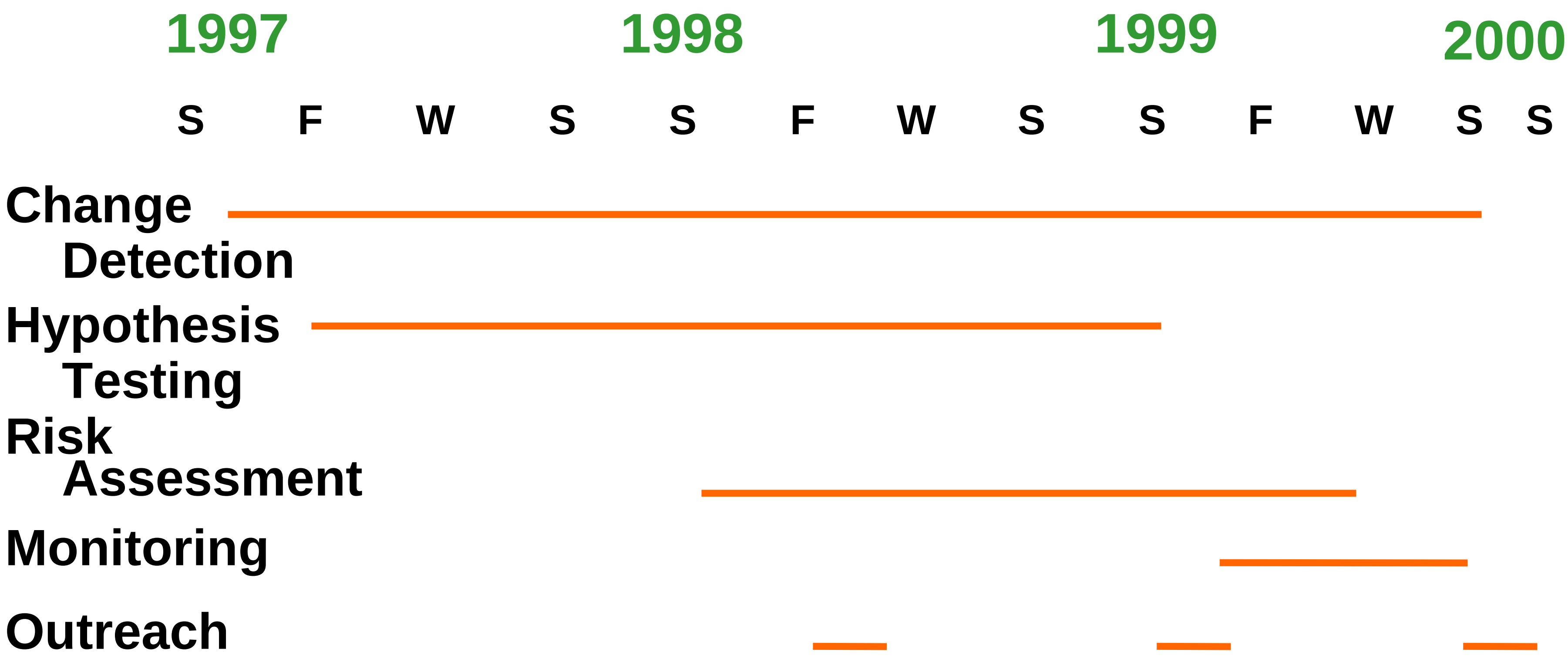
Approach

- Identify methods and data sources to "Take the pulse of the GYE" periodically.

Objective 5: Outreach

- Workshops: Bozeman, MT 1998, Jackson, WY 1999, Cody, WY 2000.
- Presentations: >15/yr to science, policy, management forums.
- Tools: land use model, risk assessment approach, socioeconomic workbook.
- Data: MSU:GYE Clearing house
- Media: Radio (Living on Earth, Morning Edition, High Country News Radio); Press (local newspapers and magazines).

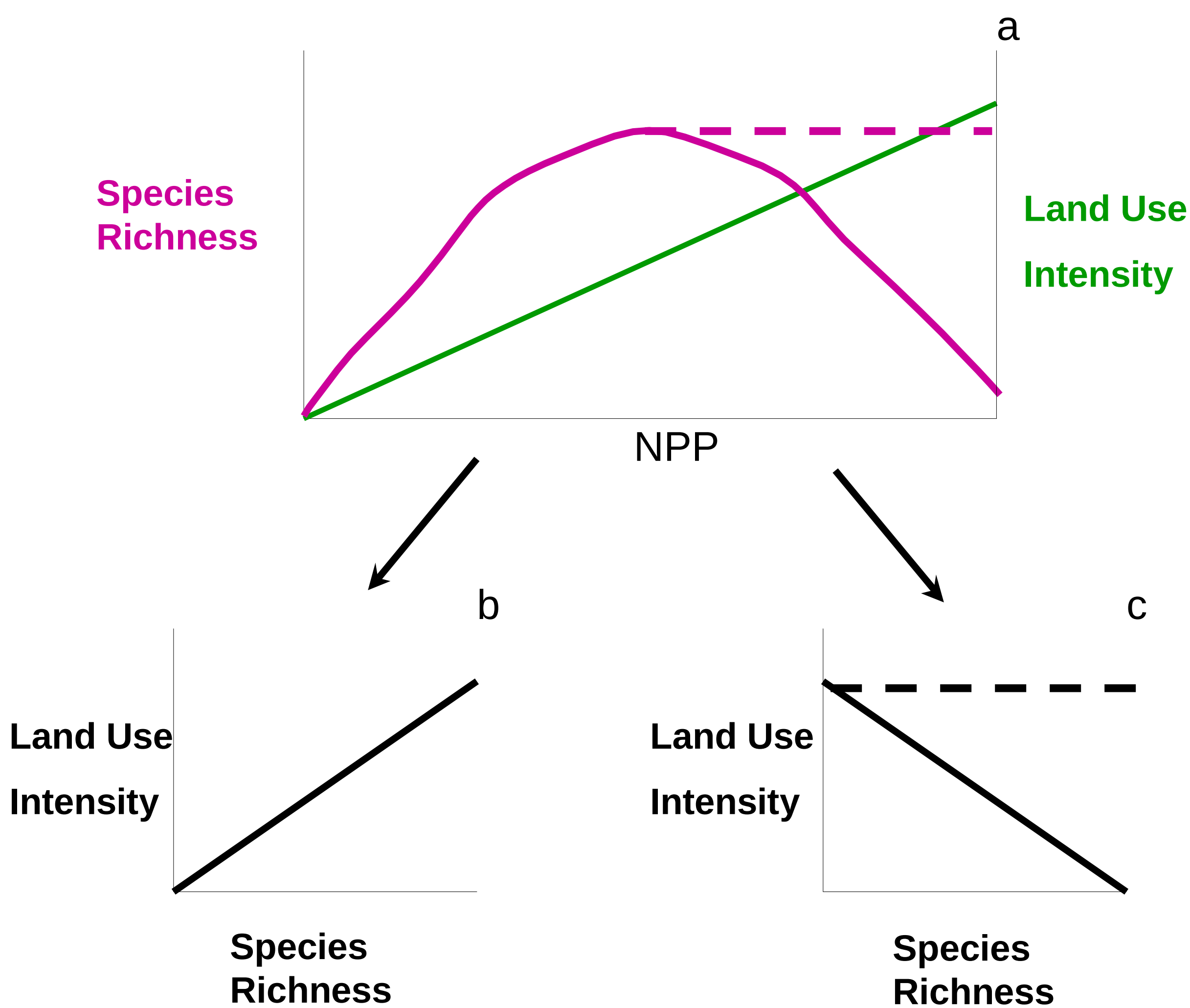
SCHEDULE


1997
1998
1999
2000
S F W S S F W S S F W S S
Change Detection
Hypothesis Testing
Risk Assessment
Monitoring
Outreach

Next Steps

- **GYE: Validation, Monitoring (e.g.,** Hansen and Rotella. IN Review. Indicators of biotic integrity and diversity in Greater Yellowstone: Development, validation, and application. **EPA.**
- GYE: Population Viability (e.g., Hansen and Rotella. In review Avian Population Viability in a Greater Ecosystem: Interactive Effects of Climate and Land Use. USDA-NRI.)
- **Regional Comparision (e.g. Interactions among biodiversity and land use across greater ecosystems.**

Generality to Other Greater Ecosystems

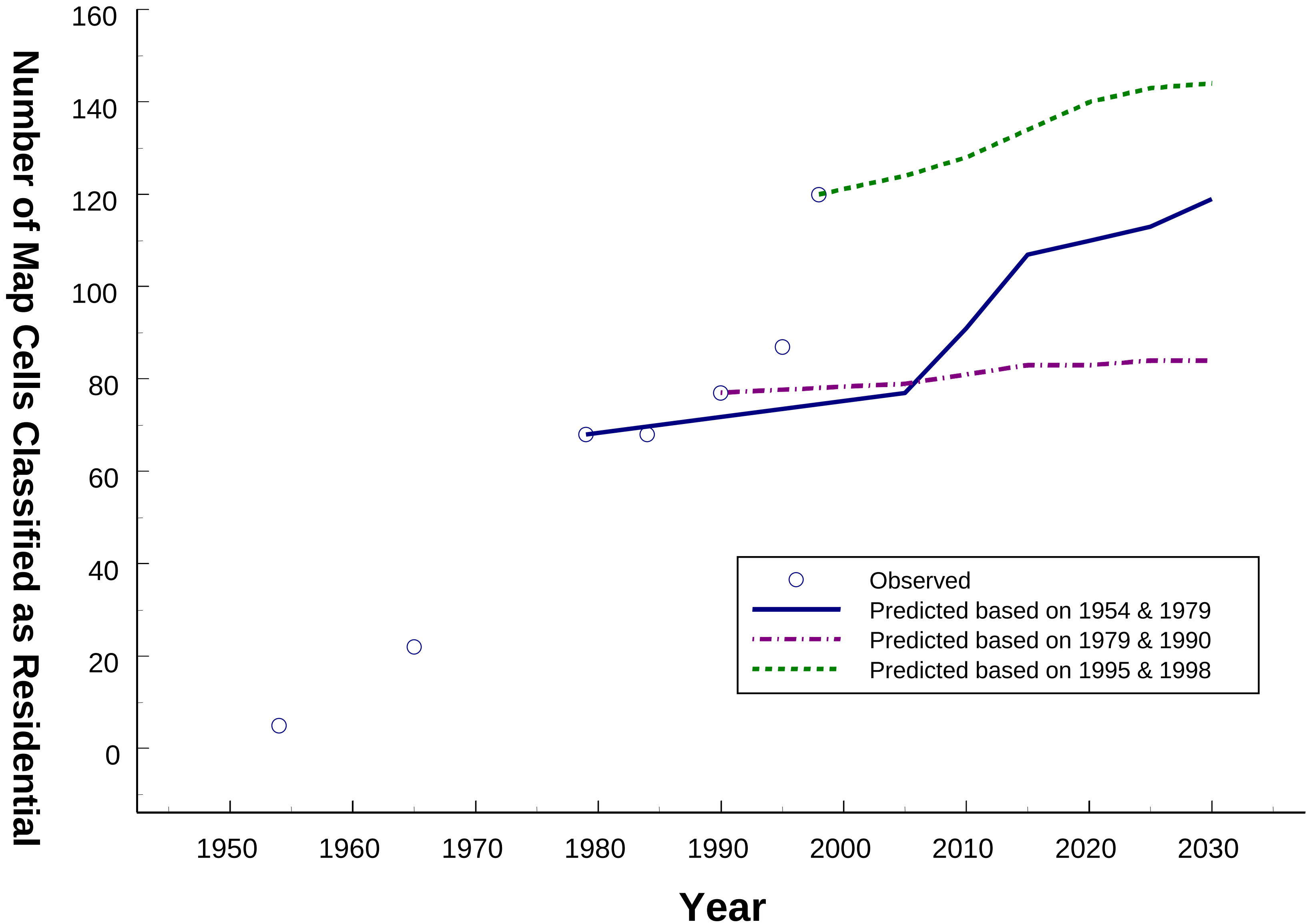


Land Cover Classification Methods

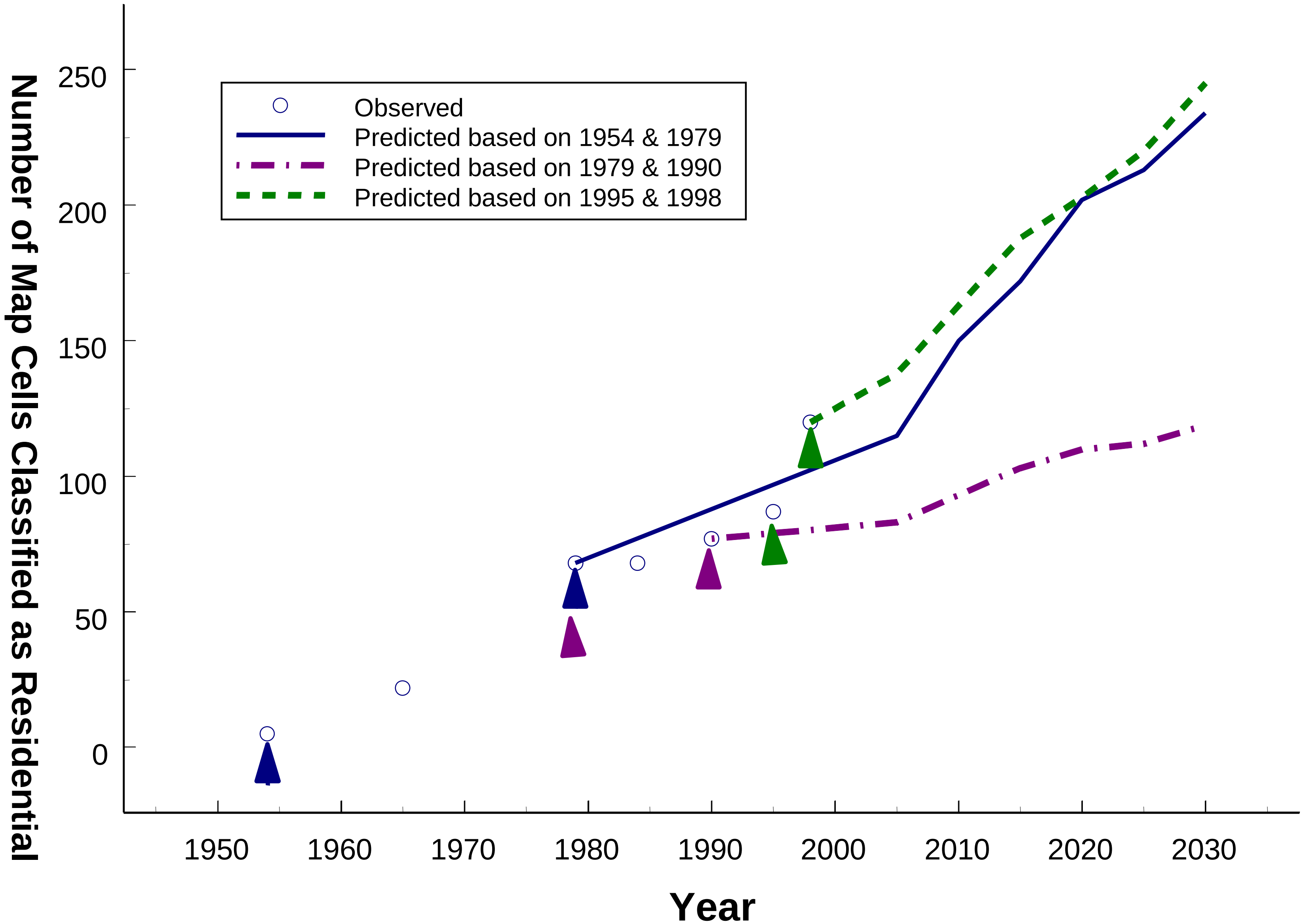
Change Detection

- **1. Obtain imagery:** 1976 Landsat MSS, 1985 Landsat MSS and TM, 1994 TM
- **2. Identify difference thresholds:** examine multispectral imagery and denote changes in cover type between 1985 and 1994
- **3. Determine change function:** identify type of previous cover type for areas that change
- **4. Assign cover type:** for each pixel in imagery. For cells unchanged, assign 1994 cover type.
- **5. Validate for accuracy:** use independent data

South of Bozeman Study Area
using nearest neighbor layer



South of Bozeman Study Area



Correlation-based designation of single ground control point